THE JOURNAL OF

Industrial Engineering

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PRESIDENT'S MESSAGE

Changes in Organization of AIIE

By Howard P. Emerson

President, American Institute of Industrial Engineers, Inc.

The affirmative vote of the membership to revise the constitution and set up a new position of First Vice President necessitated a reorganization or rearrangement of jobs in AIIE.[1]

The Committee on Organization prepared a proposal which was reviewed and revised by the Executive Committee and approved by the Board of Trustees.

As experts on organization, it had seemed a routine matter for industrial engineers to organize their own society. Like any other organization, however, AIIE had grown like Topsy until 24 individuals reported to the President. Furthermore, a professional society is not operated like a factory or other industrial enterprise. One difference is that the Business Administrator, at present, is the only paid official on the organization chart.

Principles of Reorganization

The normal step when one officer becomes overloaded is to delegate and thus divide his responsibilities. How should they be divided in this case? The principle adopted was as follows:

1. The President should deal with plans and policies, as well as the general direction of the organization.

2. The First Vice President should assist by supervising the carrying out of these plans and policies by those responsible for doing so.

[1] For a complete description of AIIE organization, see President's Message, November-December, 1955, issue, by E. L. Slagle.

This breakdown gives the President 10 advisors: the First Vice President, the administrative staff officers, and the planning committees. The line organization under the First Vice President is made up of 6 Regional Vice Presidents and 9 Directors of AIIE activities. (See accompanying Organization Chart.)

Organization Chart

Certain aspects of the jobs on the Organization Chart are not self explanatory. Some of the advisory officers have administrative duties:

Executive Secretary. In addition to advising the president, the Executive Secretary prepares the agenda and provides information for the Executive Committee and Board of Trustees. The Business Administrator who runs the National Headquarters Office operates under his direction.

Treasurer. In addition to advising and reporting on financial matters, the treasurer also this year acts as Budget Officer.

Executive Committee. The above officers plus the First Vice President, President, and the immediate Past President constitute an Executive Committee which meets regularly, once a month, carrying on for the Board of Trustees between its semi-annual meetings.

Journal Editor. The editor of the Journal is in a class by himself, acting as he does as mouthpiece for AIIE and the profession. He is ex-officio a member of the Committee on Publications Coordination and Plans.

Planning Committees

The Presidential committees marked P on the chart do long and some short range planning for AIIE. With no specific day to day administrative responsibilities, these committees can provide the necessary thinking and guidance to the President and Board of Trustees in planning and developing AIIE and its relationships with other organizations and the engineering profession.

These relationships do not appear on the organization chart. AIIE holds Associate Membership in the Engineers Joint Council and will be admitted to full membership when total of Senior and Associate members passes 5000. It has a working relationship with the Engineers Council for Professional Development, being asked to recommend a panel of AIIE members to help in accrediting Industrial Engineering curricula.

ORSA and TIMS

Recent progress in relationships is indicated by arrangements for a Symposium on System Simulation to be held in connection with the AIIE Conference and Convention in May, with the concluding session open to those who attend the AIIE conference. Since industrial engineers apply results of science and research to industrial problems, close relationship is desirable with organizations which deal with these fields, such as The Institute of Management Sciences and the Operations Research Society of America.

Annual Symposium

One of the important activities related to AIIE which does not show up on the organization chart or in job descriptions is the Annual Symposium organized by the Long Range Planning Committee. Participating in this Symposium are representatives from industry, from universities, and from AIIE. Two days each year are spent in concentrated review of some industrial engineering functions. Last year, for example, the definition of industrial engineering was formulated. This year statements were developed interpreting the definition to various groups, to top management, to foremen, to laymen and to high school students. At this year's meeting opportunity was also taken to present the new organization chart in preliminary form for the opinion of the group. Such developments as this, growing out of, but perhaps not originally contemplated in the AIIE organization, are of great importance to the future development of AIIE and the profession as a whole.

Regional Vice Presidents

As elective officers, the Regional Vice Presidents have key responsibilities, emphasized by heavy lines on the chart. No longer can the president, even with help of a First Vice President visit all chapters. The Regional Vice Presidents therefore represent the national organization in their respective regions, visiting chapters, organizing regional meetings, stimulating new activities. They report each year to the National Convention.

Directors

The directors are really coordinators. Some of the director positions require special explanation.

Special technical committees on research under a Director of Research do not carry out research as such but keep in touch with developments and stimulate research in their respective fields.

Functional committees have regular continuing duties, administrative rather than technical in function. An example is the Membership Qualifications Committee (MQC), which meets periodically to review new membership applications.

National Responsibilities of Local Chapters

A development illustrating the importance of local initiative is the assumption by many senior chapters of responsibilities for certain national functions. This development was not contemplated in setting up our organization, nor is it covered in job descriptions or organization chart. New Activities along this line include the Opportunities Service for job placement information started by the Columbus, Ohio, chapter and an I. E. Scholarship Award for high school students started by the Fort Wayne, Indiana, chapter.

Organization Manual

Job descriptions for each position on the Organization Chart have been compiled into an Organization Manual prepared by the Committee on Organization.

Results Expected

By lessening the load on the President, more candidates, leaders in the profession, should be available to run for this office. The First Vice President's position may attract candidates with abilities in getting jobs done; the position could also be a training ground for the presidency.

Two of the most important squares on the chart have not been mentioned, those marked Senior Chapters and Members at Large. These represent the grassroots. The individual chapters and members together with the complex of committees, directors, and officers are AIIE.

The ideal procedure in an organization like AIIE, with administrations and voluntary unpaid personnel changing from year to year, would be the careful drafting of job descriptions, then judicial selection of individuals to fill each position, finally handing each his job description with the instruction, "just carry out these functions, thus advancing the progress of AIIE, and a year from now turn in your annual report of work accomplished." In a sense this is what we try to do, with the National Headquarters Office available to help, and the officers available to coordinate and give direction to the work of the various committees and directors.

Finally, the organization of AIIE is not the organization

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NATIONAL ORGANIZATION

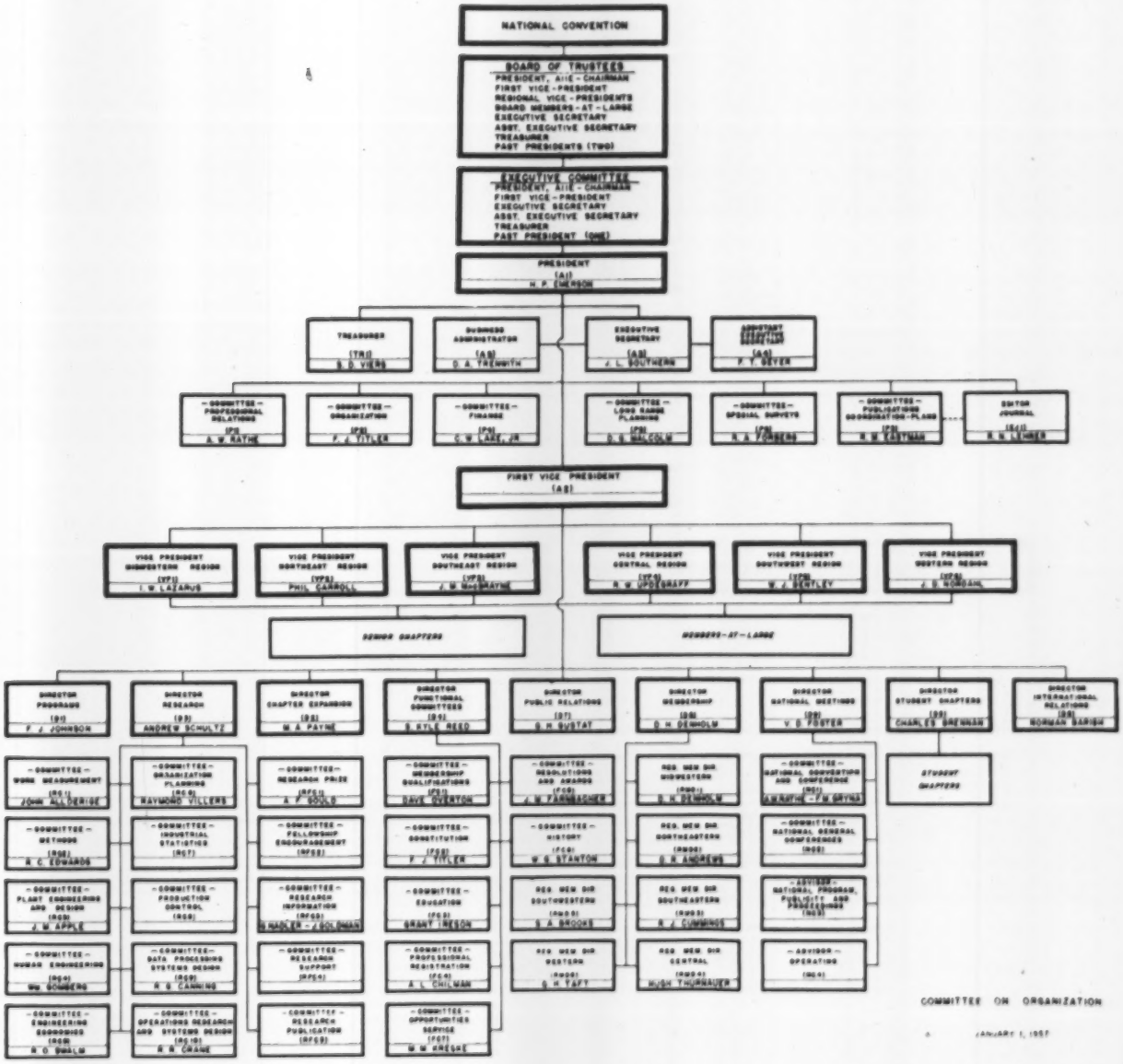

chart itself; rather it is those individuals filling the positions on it and working creatively in the structure of interrelationships which the chart defines.

Mr Floyd Titler, Board Member at Large and Chairman of the Organization and Constitution Committees, active from the beginning of AIIE as member and officer of the Cleveland, Ohio, chapter and of the national organization, was elected by the Board of Trustees in January to serve as the First Vice President. Opportunity is thus provided this year to try out the new relationships described in this message.

I. E. OPPORTUNITIES

The United States Employment Service and the affilated State Employment Services throughout the country are an excellent source of information for the active job seeker.

There are 1500 full-time state employment offices in the United States. These offices are operated with funds supplied jointly by the Federal and State Governments, usually in conjunction with the State Unemployment Insurance offices. Since this function has federal and state support, neither applicant nor employer are required to pay a fee.

These offices provide counselors, professional employment specialists, testing facilities and statistical data of interest and use to both job applicants and employers.

If a local search for men to fill jobs listed by employers proves unsuccessful, state and national listings are made. Most local offices will have state listings immediately available to applicants. National listings are maintained in the state office and are available through the job seeker's contact in the local office.

If you are actively searching for a new position consult the state employment office in your nearest major city. The interviewers can acquaint you with the latest available information on job prospects in your immediate area plus additional data on state, regional and national listings.

Don't make the mistake of classifying your state employment service as an unskilled labor source only. Through the use of special personnel, trained to handle professional employment problems, they can provide you with the information and leads which are otherwise very difficult to obtain. The information you give them will be kept confidential.

On December 7th, 1956, your Opportunities Service began supplying the chapter Opportunity Service Chairmen with monthly listings of all openings known to us. A new and revised list will be published on the first Friday of each month for a trial period. For information on specific openings, contact:

Malcolm M. Kreske, P.E. Chairman
Opportunities Service Committee
American Institute of Industrial Engineers, Inc.
Dept. OP
145 North High St.
Columbus 15, Ohio

POSITIONS AVAILABLE

P-22 Teaching position. California. Ass't. Prof. of Industrial Engr. Graduate degree and good background in statistics. Industrial exp. desirable. Primary work will be methods and standards. Excellent salary scale and opportunity for further graduate study. Position to begin September 15, 1957.

P-31 Paper Mill Co. Wisconsin. I.E. trainees, age to 30. I.E.s with 1-5 years exp. Degree in I.E. or related field. Analysis of methods, equipment, materials and product design, organization and processing. Complete responsibility for project assignments.

P-40 Client of Consultant Co. Southern U. S. Director of I.E. Strong administrator desired with ability to secure cooperation of executives. Mass production exp. involving accurate measurements. Supervise 18 I.E.s at main plant and 150 at branch divisions. $20,000 salary range with 50% bonus potential.

P-42 Hospital, Ohio. Staff I.E. position FEMALE graduate I.E. desired. Equivalent exp. background acceptable. Position created as result of I.E. survey by Management Consultant Co.

MEN AVAILABLE

M-13 BSME Norwegian Institute of Technology. Factory Management major. Age 25. 2 yrs. exp. as section leader in planning and operation of maintenance workshops (automotive). Interested in immigrating to the U. S. from Norway.

M-14 BSIE 5 yrs. exp. in electrical and metal fabrication fields in time and motion study, work simplification, standard data, cost reduction analysis, plant layout, etc. Interested in senior I.E. methods, standards or plant layout position. Desires northern New Jersey, New York City, Southern Florida or Southern California.

M-15 20 yrs. exp. in top echelon positions with major U. S. companies. Complete supervisory responsibility for I.E.s, general foremen, etc. Automation background and exp. in cost reduction, incentives, material flow, office methods, etc. Former professor I.E. subjects. Interested in foreign assignment or west coast.

M-16 BSIE Reg. P.E. 8 yrs. exp. in methods, time study, plant I.E. and production control supervision. Active in civic affairs. Technical faculty instructor. Desires position as production control dept. Supervisor or Chief I.E.

Summary of the Industrial Engineering Symposium, Purdue University, November, 1956

Reported by Austin Weston

R. R. Donnelley & Sons Company, Chicago

The third such Symposium, sponsored by the AIIE Long Range Planning Committee, was held at Purdue University on November 15th and 16th. These symposiums bring together leaders in the academic, consulting, and industrial fields to provide a basis for the orderly growth of the profession, and to indicate to the AIIE desirable programs to undertake. This group has been particularly interested in the role of Industrial Engineering as an engineering discipline and the proper development of Industrial Engineering within the scientific framework surrounding all branches of engineering. In a previous meeting, the group developed a definition of Industrial Engineering which was officially adopted by the AIIE. (This symposium was reported in the May-June, 1956, issue of the *Journal of Industrial Engineering*. The Industrial Engineering definition, as developed by the participants, was subsequently adopted by the AIIE Convention in May, 1956. The official definition appears on the back cover of the *Journal*.) Other recommendations led to the sponsoring of a "Systems Simulation Seminar" to be conducted at the 1957 National Convention in cooperation with the Operations Research Society and the Institute of Management Sciences.

The Purdue Symposium was primarily concerned with communication and understanding of the Industrial Engineering definition. It was concluded that most of the other problems facing the profession, such as curricula design, organization and direction of research, proper publicity, and the attractiveness of the profession as a career, could not be properly approached unless the basic mission of the Industrial Engineer was communicated to and understood by all concerned. As a result, the members of the Symposium decided that, while the definition need not be changed, it should be expanded and interpreted for specific groups. Four expository paragraphs were developed, each one aimed at explaining what an Industrial Engineer is and what he does. Each of the four paragraphs were written in terms which would mean most to one of the following groups:

1. Management
2. Employees in Industry
3. Engineers and Other Staff Groups
4. The General Public (with special emphasis for High School Students)

These interpretations were recommended to the AIIE as aids in promoting better understanding of the Industrial Engineering profession. They are presented, not as the last word on this subject, but to provide a basis for future discussion and for use where appropriate.

1. *Interpretation for Management*[1]

The Industrial Engineer makes an engineering contribution to achieving management's objective, primarily that of optimizing the gains and minimizing the risks of an enterprise. He assists every level of management by originating and developing operating plans, programs and controls which will permit the increasingly effective use of human and economic resources.

This is accomplished through stimulating and working with other staff and line departments in such fields as:

- **making location and site, layout and handling plans**
- **designing organization and operating procedures**
- **designing controls for organization functions**
- **designing tools and equipment, work processes and methods**
- **designing compensation plans**
- **determining the most economic way of procurement and use of materials**
- **analysis and evaluation of data and other information required for these planning tasks**
- **conducting research in these areas**

2. *Interpretation for Employees in Industry*

The Industrial Engineer is a fellow employee who is concerned with the problem of finding easier ways for you to do your work. He is not your

[1] "Management" is defined to mean anyone with line responsibility and authority to direct others in any type of activity; everyone from President, General Manager, Superintendent to Foreman.

boss, but is merely an advisor to you and your foreman. Obviously he is not as skilled in doing your particular job as you are, but he does have certain special training and experience, especially in the analysis of work. With your knowledge of the job, and his knowledge of ways to analyze and study work situations, he can help you work out an easier way to get your job done. As easier ways to do your job are found, costs will be reduced, and your company will be able to sell your products at a lower price. This will create a greater demand for your products and more jobs.

Not only is the Industrial Engineer interested in improving what you, yourself, do, but he must be concerned with those things which affect your production, and over which you have no control. The equipment you use, its position in the plant, the building in which you work, the way in which your work is scheduled, and the condition of the work you receive, are examples of these factors. He also works with the various levels of supervision on matters not directly related to production, but of importance to the continued success of your company.

In his role as an advisor to you, your foreman, and other management people, he is continuously looking for further improvements, and therefore is never satisfied with things as they are. He attempts to keep up with the best practices and newest devices, in order to make sure your company is always doing every job in the best possible way. In performing his job the Industrial Engineer must work in different areas and with many people in order to help achieve the company's objectives.

An example of one of the activities of the Industrial Engineer is to determine the time required to perform operations. This time may be used as the basis for compensation, to determine the costs of producing the product, for balancing the production lines and other purposes. Other activities that are frequently performed are the determination of the best location of plants, the proper equipment to use in manufacturing processes, better materials and devices for you to use and insuring that the plant is engineered for safety.

3. *Interpretation for Engineers and other Staff Groups*

It is important to differentiate between the concept of the Industrial Engineering approach and the organizational function entitled Industrial Engineering. This can be done by determining what the Industrial Engineer does for management; what is the Industrial Engineering approach? The Industrial Engineering approach is a unique application of engineering design and analysis techniques, frequently not as sophisticated analytically as in the other, older engineering areas.

The Industrial Engineer's consideration of people, the design of systems involving people, and the manner by which human performance is analyzed requires a fundamental, analytical approach that is essentially different from other engineering disciplines.

The contribution of the Industrial Engineer is in the management decision making process. The problems existing in this area deal with the optimum utilization of men, materials, equipment, and energy to achieve the purpose of an organization. The organization may be an individual department of a company, a hospital, an entire corporation, or any other group organized to produce a product, perform a service or carry out a function. The managers of the organization need factual information arranged to define alternatives and consequences, to help them recognize and solve existing problems. The Industrial Engineer collects, analyzes, and arranges this information in such a way as to fulfill this management need, as well as searching for better ways to do the job. The Industrial Engineer operates in two major areas, the design of new systems and the maintenance and improvement of existing systems.

To summarize, in his work the Industrial Engineer:

1. Identifies problems, gathers facts and appraises difficulties.
2. Visualizes solutions and designs, develops or improves systems.
3. Searches out requirements for quality, quantity, cost and timing.
4. Makes and justifies results of economic analyses.
5. Specifies, constructs, installs and, sometimes, initially operates these systems.
6. Devises methods of controlling and of evaluating the performance of systems.
7. Develops acceptance by and secures cooperation of those who operate such systems.

The Industrial Engineer is distinguished from other engineers in that he:

1. Places increased emphasis on the integration of the human being into the system.
2. Concerns himself with the total problem.
3. Predicts and interprets the economic results.
4. Makes greater utilization of the contributions of the social sciences, than do other engineers.

4. *Interpretation for the General Public* (with special emphasis for High School Students)

The Industrial Engineer is an engineer who is concerned with the design of industrial enterprises or other types of organizations existing for a worthwhile purpose, the planning or blueprinting

of the combination of men, equipment and materials necessary to produce most effectively desired goods or services. The Industrial Engineer differs from other engineers in that his fundamental concern is with operations that result from both physical and human forces, and are measured in both physical and economic terms. Therefore, he is educated not only in the engineering methods of analysis and design which stem from mathematics and the physical sciences, but also is concerned with psychology, physiology, sociology economics, costs, and human relations.

He may be dealing in the automation of the manufacturing process, in the development of methods of handling materials, in the development of procedures to control production, or to measure performance of any type of work. He frequently serves as management's advisor in the solution of special problems.

In doing his job he comes in contact with all functions of an organization and employees at all levels. He must be able to deal, not only with the technical aspects of his problems, but also the human. Philosophically, he is devoted to the ideal of helping the nation to use most effectively its physical facilities and human talents for production of goods and services.

A person considering industrial engineering as a career will find it one of the most rewarding in terms of challenge, recognition, and satisfaction. The Industrial Engineer starting on his career receives the excellent financial compensation consistent with that of other engineers. The modern Industrial Engineer in performing his role, not only utilizes the traditional engineering tools and techniques, but, also, makes effective application of such new developments as electronic computers and modern data processing devices. In addition the many new developments in management science are best applied by individuals with the type of education and experience possessed by competent Industrial Engineers. Many Industrial Engineers, by virtue of their area of endeavor and the breadth of their experience, have and will continue to progress into top management.

Future Activity

Plans were made to build next year's Symposium around Industrial Engineering systems design. Several members of the group will prepare case histories based on their experience to illustrate how the Industrial Engineer (using the wording of the definition) "is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment." From these, the group plans to develop one or more concrete examples of the highest type of creative systems design, expressed in non-technical language. It was felt that such examples would stress the unique engineering approach of the Industrial Engineer, illustrate how the Industrial Engineer applies scientific principles and methods, and help locate this function in an organization structure. Georgia Institute of Technology was selected as the host for the next Symposium, to be held in the Fall of 1957.

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Michigan State University
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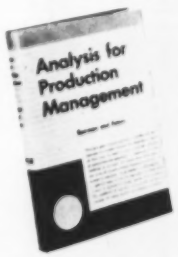

By EDWARD H. BOWMAN and ROBERT B. FETTER, both of Massachusetts Institute of Technology

This new book presents some of the latest methods of analysis that have been developed to solve problems of production management. Each of these methods of analysis—in the areas of mathematical programming, statistical analysis, and economic analysis—is illustrated by a specific manufacturing problem. The methods of analysis are operational and are capable of being applied to real problems.

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Automation and Time Standards

By Bernard N. Roth

Industrial Engineer, Insulating Materials Section, Chemical Materials Department, General Electric Company

My paper's title might be rightly called a "triple entrendre" as I hope to encompass three subjects, all described by that one title. I am going to tell you about a method of determination of standard time that:

1. Is economically and statistically of the order of accuracy needed for automation.
2. Provides the system analysis, or stochastic model of the system for operations research, line balancing, and other improvement techniques.
3. Is in itself automated to the degree that all computations and statistical manipulations are mechanically performed.

The need for prediction of labor content, operation times and cycle times within confidence limits and known degrees of accuracy is fundamental to economic process analysis or automation study and is a primary criteria of effective process management. While the primary "sale" of time standards in repetitive production has been for use in labor cost control, in process industry the emphasis must be on use in the planning of facilities.

Standards for labor control takes on importance in process industries mainly in service areas such as maintenance, materials handling, and paperwork. And in these areas, due to the diverse "nature of the beast", the difficulties created by the noncyclic aspects, we find that other techniques are supplanting stopwatch set standards. The trend in process and automation technology is towards less repetitive manual work, the substitution of machine for "direct labor", and the creation of jobs to adjust, guide, and service these machines. Here again, labor content is low, and stopwatch technique becomes marginal.

I want to briefly sketch some of the criticisms of stopwatch time study; these are reported views and must be rejected or concurred with in the light of your own experience.

1. The accuracy of the standard is not calculable. Various semi-statistical techniques have been used to check accuracy, but they are based on the statistics of random sampling, and not rigorously applicable.

2. Stopwatch technique is difficult to apply to craftsmen or whitecollar workers from the employee relations standpoint, and again, trends show that employees are moving more and more into these categories.

3. Allowances for interruptions and leveling of pace are not scientifically determined and applied.

4. The psychological factor of performance under continuous stopwatch observation cannot be evaluated in terms of representativeness on the part of the worker or the observer. (The more complete philosophical and scientific criticism of stopwatch technique can be read in Adam Abruzzi's "Work Measurement" and in Gomberg's "A Trade Union Analysis of Time Study".)

To a large extent, standard data systems such as MTS, and others such as MTM, have overshadowed and minimized these criticisms in their application to repetitive work. In process industries we are beset with elements that must be measured and standardized, elements that do not vary with distance or with weight lifted, e.g. patrolling instruments, sweeping, painting, manipulating valves, etc. Usually these elements are repetitive over a long cycle, and become uneconomical to time by stopwatch.

In synthesizing the irregular peg for the non-standard hole we want for process industry, a technique:

1. That will be economical
2. That will have calculable accuracy
3. That will give us a model or a picture of the entire system
4. That will furnish standard data, or building blocks for predetermined standards
5. That will be impregnable against criticism by irresponsible *or* scientific elements
6. That will permit us to bury the "crystal ball"

I believe that we have "cracked the valve" on a technique that fulfills the above synthesis. Simply expressed, it combines random sampling of operational work and interruption elements of labor and equipment with production statistics for the period of observation, and automatizes the handling of the data by taking observations on mark sensing IBM cards and processing all data and calculations through the standard electric accounting machines available in most plants today.

Let's hit each of these techniques separately and see how they mesh into a new technique.

Random sampling was originated in 1935 by L. H. C. Tippett in the English textile industry and applied to determine delays and multiple machine assignments. The technique was reported in theory by R. L. Morrow in his textbook and christened "Work Sampling" by C. L. Brisley, who reported an application to wire drawing at Anaconda Copper in Factory Magazine in 1952. As the name implies, the technique employs random spot observations of activity, usually predefined. The percentage of observations of each activity mirrors accurately the per cent of time spent by the observed equipment and/or operators on that activity. This technique by itself is very useful for diagnosis of trouble spots in a system, and for derivation of multiple assignments.

By combining random sampling of defined work elements, operations, and delays with accurate production information, standards can be computed for elements and/or operations. To illustrate, we load a filter-aid into our blenders to increase filtration clarity. During our observations we ran 200 batches, utilized a total of 2000 labor hours and found that the per cent of observations of filter aid loading compared to the overall number of observations was 2%, for example. The average time per filter aid addition was therefore 0.2 hours. (Figures are hypothetical.) Use of sampling statistics can give us the "tolerance" and confidence limits on the time value, or the odds that certain quantitative limits exist on the stated time. Use of random sampling for pace or skill and effort ratings and for determination of valid allowances can give us a standard time for the element.

Realizable accuracy of standards goes up with number of observations, as it does with stopwatch techniques. Handling and computing a large number of observations, particularly if validation work is attempted, and more so if a statistical model is desired, becomes increasingly laborious, cumbersome, and fraught with possibility for error as the number and detail of observations increase. In handling this mass of data, automation is economically justified. By keypunching observed data into accounting machine cards we can program computations, and cross sort with ease. If we go one step further, and use an electrographic pencil to mark sensititized coding of data on cards, manual keypunching is eliminated and further economies result, as well as minimizing errors inherent in transcription.

Essentially, the system as synthesized includes:

1. Random sampling of defined activities on,
2. IBM mark sensing cards,
3. Combining information with production data, and
4. Performing sorting, other manipulation, and computation on electronic data processing equipment, to
5. Present standard activity time data, allowances, group "Output" factor, all with known accuracy limits, and
6. A statistical model of the overall operation, useful for the derivation of operational relationships and analysis of variable for diagnosis of trouble spots.

A case history of the application of these techniques can illustrate its usefulness in process industries.

We were faced with the problem, in early 1955, of keeping pace with a sharp increase in sales volume, due primarily to the securing of new large accounts. As you all know, new, heavy processing equipment requires quite a time cycle from conception to on-stream installation. It was obvious that going from 3 shift 5-day operation to 7-day operation would not satisfy demands. A hard hitting taskforce initiated a complete study of existing capacity in an attempt to "stretch" it.

Our resin process generally follows Fig. 1. Materials, liquids and solids are charged by weight into second floor kettles from the third floor. The materials are reacted at temperature for a period of time until the wanted degree

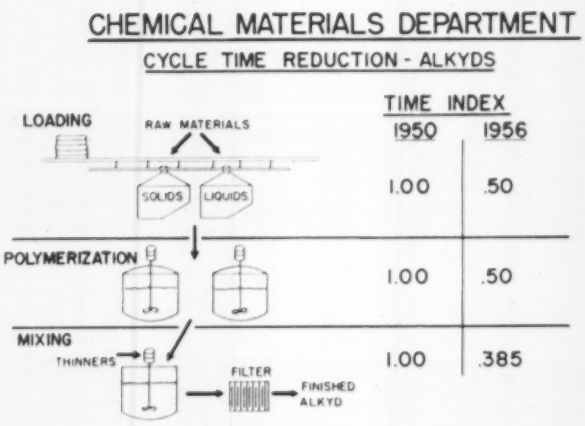

Fig. 1

of polymerization as determined by test sample is reached. The hot resin is dropped into blenders on the first floor into cooled solvent, which

1. Cools the resin to workable temperatures.
2. Stops the reaction from continuing and changing desired properties.
3. Dissolves the resin to form a solution which can be more easily pumped, packaged, and handled by us and utilized by the customer than a pure resin, which generally has a very high viscosity.

The resin solution is then tested, filtered, and pumped to storage tanks awaiting bulk shipment or packaged in drums for use by smaller volume customers.

A preliminary analysis of the production system revealed that excessive cycle time in loading and mixing room phases were reducing kettle utilization markedly. The loading process, serviced by two men and two sets of loading equipment was successfully analyzed and bottlenecks resolved through standard flow chart techniques. Decreasing the reaction time is a chemical processing problem primarily and is not germane to today's discussion. The mixing room phase is typical of the necessary approach.

The mixing room facilities include three sizes of mixers and filter presses, 13 mixers, 10 filter presses, storage tanks, and process piping. The average crew is six men. A mix of about 100 product grades are processed.

Consider the complexity of setting standards on this type of an admixture with stopwatch technique. Standards for each product grade would require a total of 2100 hours observation time for a one cycle/product observation period. Comparison of similar elements and computation of standards by the test techniques would take many hours to handle the mass of data. Contrast your own experience with stopwatch of cycle time to overall time/standard. On top of this, a methods study to minimize the cycle, plus interactions of men and equipment, inter-

ference, etc. were needed in diagnosing and correcting trouble.

A preliminary analysis of mixing room operations led to familiarization with elements, delays, and activities. In designing a sampling data sheet, we soon saw that the handling and cross correlation of data would be a stumbling block in getting results rapidly. This realization led to the innovation of using IBM equipment and finally mark sensed cards to simplify data handling and computing.

Design of the field matrix for the mark sensing card followed discussion with our own IBM specialist and IBM service personnel. Two junior engineers were assigned to help in taking data (although experienced time study men could have been used if available) and were familiarized with the mixing room, with the defined activity elements, with the coding and marking system and with tour and observation method.

Finally, before taking the study, sampling was introduced and demonstrated to the foremen first and then the operators as a diagnostic tool. The observers were introduced to the shifts they would be associated with. Both supervision and hourly employees were cognizant of our capacity problem and were "sold" sampling as a solution that favored our *collective* success in satisfying customer needs.

The observation tour consisted of mixing 30 cards designated with a mixer number, filter press number, or personnel designation, and taking component activity observations in the order of cards turned up. Observation point for each piece of equipment was designated, and observer instructed to take "snap" observation on reaching that point. Personnel tending equipment were also observed from the same point. Upon completion of one tour a short rest period would precede the next tour. Essentially we had random observations with respect to sequence and time, which eliminates the "contact" factor prevalent as an unknown in stopwatch work.

Cards were marked for date and hour of observation, gross system, equipment number (or personnel, with no differentiation) general and specific activity element, product number, leveling factor, and observer. Dry runs established about 1½ tours/hour as the normal goal. This meant that roughly 25,000 observations would be taken. To simplify observing, a clipboard was fitted with a jig to hold and locate cards and with pockets for both marked and unmarked cards.

As our IBM machines are constantly in use, set up economies and capacity problems forced us to batch all of our cards and run them through the machine processes in one run, otherwise cards could have been processed each day and results tabulated sooner.

The cards are processed as follows:

1. Mark sensing punch—convert conductive graphite marks to punches in desired field of card. Also, as a check on accuracy, indicates as errors cards which have marks (or punches) omitted and those that have duplicate contradictory markings. Rate 100 cards/minute.

2. Reproducer punch—is activated by programming section of card and reproduces date and hour for each period. Also simultaneously reads punched master data and indicates errors. Rate—100 cards/minute.

3. Sorter—sorts information into desired pattern of analysis for tabulation by any of the classification listed and in any order of classification. Thus, if we wish to analyze variation by hour we sort by activity and hour and cards will be summarized for each activity by hour. We can in this manner contrast shifts, equipment capacities, periods before and after shutdowns, products, observers, etc. The sorter also spots error. Rate—600 cards/minute.

4. Tabulator—counts and prints or decodes information from sorted cards. These printed tabulations give basic data for analysis of operation and delays. A simple error location device is again built in. Rate—100 cards/minute.

Another advantage of cards is that they form a compact record of observation and any further analysis of data resulting from the planned analysis can readily be had by additional machine processing.

Two final auxiliary machines that were used are a collator, which merges cards separated for certain analyses back to the sorted condition that existed before separation, and a key punch, which mechanically reproduced error cards caught by the machines in context, except for errors, which were corrected by manual punching.

Analysis of the data pointed out quantitative advantage of continuous operation, correlation of personnel interference with capacity, personnel utilization and applicable corrective measures, queuing problem in product inspection (and its resolution), excessive blending time, scheduling improvements, and quantitative value, need for improved instruction communications pattern, working pace of group, and also the qualitative improvements that combined familiarity with an operation and analytical ability brings forth.

Utilization of standards and recommended improvements is reducing the mixing room cycle to 38% of former time, and providing information for scheduling work crews and product batches. The entire study took 1000 man hours compared to 8000 hours that would have been required for the stopwatch technique, and two of the observers had never before taken either a time study or a sampling observation.

I should touch briefly on the statistics behind this approach. The basic method of sampling is, of course, familiar to anyone who has worked experimentally or who has observed and generalized. We attempt to observe a representative yet economically small position of a cycle or phenomena and generalize these observations to the unseen yet considerably larger position. Successful generalization can be optimized by utilization of statistical random sampling and its mathematical properties. Randomizing the time and sequence of taking observations eliminates the possibility of bias on the part of an observer in taking all data at noon and three-thirty P.M., for example, to achieve a high per cent idleness; it eliminates the possibility that the personnel being studied, who also

to an extent control the equipment to be studied, can anticipate observation and thereby give a non-typical performance. Randomizing also promotes the normality of the sample (aside from its apparent representativeness) which allows one to utilize the useful mathematical properties of a normal distribution. If all of the samples are of the same overall group or statistical *universe* or *population*, then their statistical properties should be similar. The similarity that is useful is the means of the sample, in our case the mean per cent occurrence of the sample. We can use this property and its mathematical treatment to determine whether the samples in question are taken from the same group or whether the difference in mean per cent indicates that the groups sampled are different.

This is treated mathematically through integrating of the normal, or Gaussian curve, which expresses the probable variation of a population due to chance difference. Observations outside the curve boundaries are usually ascribed to other than chance variation. Actually most work is done with tables that give probability of the observations' deviation from central tendency as a chance variation, or with set ordinates of dispersion and comparable probability. The measure of significance or tolerance used in our computations was the "3σ level" which indicates that tolerances on percentage includes all chance variation that would occur 997 times out of 1000. Thus a percentage of $24.3 \pm 2\%$ gives us assurance that 997 times out of 1000 the stated per cent will vary from 22.3 to 26.3. Similarly any per cent that is said to be significantly different from a population or other sample bears the same limits that 997 times out of 1000 the difference is due to some cause other than chance, usually to the nature of the different groups sampled.

In the correlation of "personnel present and working" with "wait for personnel" we use the "least squares" method of fitting the curve and correlation computations to check probable accuracy of the curve; in essence, comparing the unexplained deviations from the curve of the equation to the deviations allowed for in the formation of the equation. The correlation we obtained was not as good as we had hoped for; however, reasonable correlation exists.

Finally the limitations of the technique both in data handling and in statistical work. The limitations for this method of data handling do not become apparent until one attempts to process the cards. Briefly these limitations are:

1. Mark sensing requires line density in a definite space on the card. Hurried marking, improper pencil point, etc. causes omissions.

2. Machinery and cards are very sensitive to humidity. An air conditioned IBM room is recommended by the company (and by the writer after certain experiments) as conducive to machine accuracy.

3. Machinery is very sensitive to cards that are dirty or frayed. Clean and careful handling is a must. Cards should be stored in a compressed condition to avoid warping.

4. Personnel generally familiar with IBM equipment are not familiar with mark sensing technique. Until the cards are punched it is a relatively special technique. Much time and effort can be saved by getting special technical assistance in setting up a study based on mark sensing of cards.

Results must be statistically questioned before being put to use. A difference between the variable in question and its control *can* and often *is* a chance difference. Don't use intuition alone, back it up with a check of the significance of difference and analysis of the variance. Remember, that in applying this technique to a process, you encompass the setting of many standards and also obtain many quantitative conclusions that become the basis for decisions. You don't have to be a statistician, but a working knowledge of the statistics of sampling is a must to insure a reliable study with unimpeachable results.

These are boundaries rather than limitations. Accepting and providing for these cautions, we have an economical technique that can fulfill the stringent requirements of an automation technology. The technique delineates a path, but only our own efforts will limit the span of use, or the rate of attainment.

TEACHING POSITIONS AVAILABLE

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BOX 444, CUMBERLAND, MARYLAND

The Higher Objectives of Industrial Engineering*

By M. A. Payne

General Manager, Lubrizol of Canada Ltd.

It might be suitable at a time coincidental with a meeting of our Long Range Planning Committee to loosen our imaginations a bit and give some thought to the ultimate aims and objectives of our profession. I've noticed in my own experience, those objectives which can be most clearly defined are usually the easiest to attain. I've noticed also in my Institute work a need for a clearly defined objective for the Institute and the Profession. We have had satisfactory short term goals—to increase the membership, to attain greater representation of the profession, to increase the size of the **Journal,** to establish a definition of Industrial Engineering—but I don't believe we have a clearly stated objective of the type I have here in mind.

We might begin our search by shifting the level of our thinking about our profession up one step. Review your favorite definition of Industrial Engineering. Perhaps it will be the one recently offered by the AIIE

Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems.

Now ask yourself—*Why?* For what ultimate purpose do we as Industrial Engineers do the above? What basically are we trying to accomplish?

Let's continue our search by asking some additional thought stimulating questions. Try to formulate answers to these in your mind as I review them.

1. What is the highest service an Industrial Engineer can perform? Is there a service to mankind that can only be performed by the Industrial Engineer or that can be best performed by him—a service that may be said to be unique to the profession?
2. How do we envision the idealized state of the world if the principles of Industrial Engineering were to be universally accepted and its techniques developed close to perfection? Would it be a cold mechanical regimented world operated by people the majority of whom are given no opportunity to exercise imagination or resourcefulness? If not; what part of our philosophy would keep it from being so?
3. Speaking of Long Range Planning, will the Industrial Engineer, or his basic philosophy, have a place in the scheme of things in—say 500 years? What basic philosophy of ours will so survive?
4. There are a number of fields of interest or operation associated with the practice of Industrial Engineering. Is there a common denominator to these?
5. What oath or resolution can our graduates cite as they start their careers which will serve as a guide throughout their professional life? Or stated another way, with what unique responsibilities can we charge our Industrial Engineering graduates which will direct them through life?
6. Admitting the Industrial Engineer has a recognized place in the industrial and commercial order, does he bear some special responsibility to society—unique to his profession—a responsibility not shared by others in this order? For example: Doctors, as a professional group, might assume "public health" as a special responsibility, is there a comparable responsibility which is uniquely ours which *we* should be recognizing and proclaiming?
7. The value of our profession is quite apparent to us. In what basic terms can we explain our profession so its value will be equally apparent to others?
8. Since we are considering *higher* or *highest* objectives, ponder for a moment the ultimate achievement of man and mankind according to your own religion and philosophy—love and service to God and mankind, perfection, achievement, recognition, health, wealth, happiness—these are the kind of words and terms which will be coming to your mind. Now ask yourself—are there basic tenets of our Industrial Engineering philosophy which are concerned in any significant way with this ultimate achievement? If so, how can they be expressed?
9. Suppose for a moment you arrived on a campus for the first time, or after an absence of some time, and found a group of men erecting in a prominent spot a large bronze statue of a particular Industrial Engineer. Obviously, to warrant such distinction, this would be a most outstanding man of our profession. Now ask yourself, what might this person have done as an Industrial Engineer to warrant this distinction? Is there some golden thread of our profession which this man would have found, developed, and used in his career to deserve such outstanding recognition?

It would seem our answer to these questions would somehow relate to our service to mankind, at least in the ultimate. It might, of course, be through service to institutions of men—industrial, government, social, commercial. All achievements, I believe, would be empty if they were not somehow related to service to the individual and mankind. I believe our answers to these questions would relate to a service which uniquely tends to raise man toward

* Based upon a presentation to the Joint Meeting of The AIIE Long Range Planning Committee and The Central Indiana Chapter of AIIE, November 15, 1956.

perfection. Our answers would relate to a service which permits man to most effectively express himself and achieve success in his own vocation.

For example: If a man is called to medicine, can our profession somehow find application in his struggles to approach perfection as a doctor—enabling him to give more and better attention to more of humanity—both through help to him as an individual, and through help to him as a member of a group, as in a clinic or hospital—and through help to him as a member of a larger segment of our society devoted to the general problems of health, health research, health service, and preventive health measures?

If a man is called to the vocation of a mechanical craftsman, does not our profession find application in his struggle to serve humanity through assistance to him in the application of his arts, crafts, and sciences. If he is a machinist, is it not the purpose of our professional practices to establish for him an atmosphere wherein he can produce to the fullest of his ability the arts of his trade, thereby enabling him to carry on in his vocation, the highest achievements of which he is capable?

If a man is called to a vocation in the field of politics, can we not assist him in his struggle to perfection—both as an individual and as a participant in political systems and societies?

If we consider Industrial Engineering application on a department or plant basis, are we not in effect attempting to assist the group in its struggle to reach perfection?

It is my personal belief our profession can do these things. Perhaps at this point, you feel as I do, we are standing before a tremendous opportunity, a tremendous challenge, and a tremendous responsibility. I mentioned responsibility because, while I feel service to society in this area is not totally ours, it is none-the-less ours to a very great extent. I believe because of our professional status in this field, we have a unique claim to this area of service, a claim different and distinct from that of all others.

From the ideas presented to this point, can we begin to put together the objective we are seeking to define? Certainly, I believe we are on the right track. However, before we go any further, let us recognize in establishing a goal or objective in the sense we are now discussing, we are not setting a standard. We are setting an objective which even the best of the profession aided by the accumulated experience of many more generations, will hold as an inspiration, always to be sought, but because of our imperfections, never to be attained. Only such an objective would serve the purpose I have in mind.

From what has been stated, it would seem our basic purpose is to serve mankind, to help mankind attain perfection of its abilities and talents by leading it or showing it, or demonstrating or providing the ideal atmosphere. That atmosphere which is most conducive, most stimulating, to the attainment of the perfection of its abilities and talents. This service is not limited to the individual's effort, but can apply to group effort, even to the more complex areas and systems of human endeavor.

In the broad terms with which we are dealing, we might even say as we attain perfection in our profession we will *assist* mankind *toward* perfection in all of its endeavors.

Let's pause now for a moment on this lofty peak and survey our position—not in reference to all fields of endeavor, but in reference to other fields of engineering. I would suggest that if our position is truly the one just stated, it is one unique among the engineering branches, and one for which we need never apologize—unless only, we find ourselves failing to live up to it. Certainly, no other engineering branch faces quite the challenge we must see before us.

To summarize the objective just developed, I repeat the following. (It is admittedly imperfect, but will assist the progress of this discussion).

The basic objective of Industrial Engineering is to help mankind attain perfection in the application of its abilities and talents.

Proof

To attempt a sort of proof or try-out of this statement, let us go back and check it against the questions asked earlier. Our first question was "What is the highest service an Industrial Engineer can perform?" We can now answer, "That service which helps mankind attain perfection in its abilities and talents".

How do we envision a world with our Industrial Engineering principles universally accepted? We might answer—bright indeed, if in that world each individual is encouraged, assisted to exercise his abilities and talents in an atmosphere most conducive to bring out that which is the best in him, both in his individual and in his group efforts.

Will this philosophy have a place in society in 500 years? Yes, and I dare say for as long thereafter as there are people!

Is this a common denominator of the various branches of our profession? Yes.

Does this objective have sufficient depth and meaning to provide a suitable basis for an inspirational guide for our graduates? Most certainly it does.

I won't run through all the questions presented earlier but I think you'll find the objective stated can provide a satisfactory answer to all of them.

I hope, however, to point out there is a basic element in our profession of something tremendously worthwhile—something, which if brought to focus and described, can be of real help to us in our own search to be of better service to mankind. I think we owe it to ourselves and society to seek out this element; define it to the best of our abilities, and install it in its rightful place as the goal and the basic reason and purpose of our fine profession.

I hope my words will stimulate thinking in this area. Thinking which will eventually result in the clear formulation and statement of the higher objectives of Industrial Engineering.

Proposed Program for Graduate Study in Operations Research and Systems Engineering*

By M. E. Salveson

Consultant, Operations Research & Synthesis Consulting Services, General Electric Company

OR: A Growing Opportunity

In industry and in the military, enthusiasm is growing for what is termed here "Operations Research" and its closely related subject "Systems Engineering." It is timely, therefore, that the American Society for Engineering Education, the Operations Research Society of America and the AIIE should examine how to educate persons for this new profession. Each Society has investigated this question recently, e.g. see (1, 2, 3). I am happy to offer my views as part of this examination process. Frankly, I am an enthusiast for the opportunities here. I hope that I shall be able to infect the readers, too, with a belief in these opportunities.

In order to provide the background and orientation for my remarks, I will retrace briefly some of the recent developments of OR. (I will not duplicate the extensive literature on its history and genesis which in a real sense can be traced to the Egyptian Geometers and Euclid.) I will endeavor to extract certain concepts from two recent, simplified examples and, then, trace the path via which these concepts have evolved into the current and possible future practices and attitudes in this field. This will permit me, then, to make some suggestions on graduate training for OR, at least for business and industry.

Two Simplified Examples

Two World War II applications of Operations Research, though greatly simplified, illustrate my initial concepts. The first was a problem brought to the attention of the operational commanders of the Pacific Fleet as follows: Surface radars had been installed on our submarines, thus increasing their effective horizon, say, from a radius of ten miles to fifty miles. When the submarines began to use the radar equipment, the number of contacts with enemy aircraft increased frighteningly. The submarine commanders' immediate reaction to the increase was that the Japanese aircraft carried equipment to detect search radar signals; with such equipment they could discover the submarines and "home in" on their radar signals. The immediate impulse, therefore, was to discontinue using or to remove the radar equipment from the submarines. The Fleet Commanders asked the Operations Researchers to make a study of the situation and submit their findings.

The operations researchers "theorized" that the number of aircraft sighted should be roughly proportional to the area swept by the search device, whether visual or radar, and that the area of the circle swept at any point is proportional to the square of the radius of the search horizon. It should be expected that, with a radius five times as great, the number of contacts should be approximately 25 times as great. ("Approximately" is used here for simplicity because there is an uncertainty involved in sighting an aircraft, either visually or by radar which varies as the distance from the observer.). By analyzing the results of actual sightings with vistual and radar devices with reference to this "model" or "theory of radar search", the operations researchers inferred that the Japanese planes did not have, or were not using, radar detection and homing devices. Hence, the radar was serving its purpose without adverse effect and the submarines should continue to use the radar search equipment. Post-war investigations proved the operations researchers were correct in their inference.

In the European theatre a different type of problem was encountered. The Commander of the U. S. Air Force noted that, as the number of planes in a bombing raid increased, the number of planes lost in that raid also increased. The question was should the size of the bomber fleet be smaller or larger in order to minimize losses for a given quantity of bombs dropped and bomb effectiveness. The initial belief was that the size of the bomber fleet should be made smaller instead of larger. The operations researchers studied the situation and theorized that the number of planes lost did increase as the bomber fleet size was increased, but that it was less than proportional increase. An analysis of the inter-action of the enemy anti-aircraft with the attacking bombers was made. It indicated that, with a fixed enemy fire power, the total number of hits should not increase in proportion to the number of bombers in the fleet. Thus, the conclusion was that the larger the

* Based upon a presentation to the ASEE meeting, June 1956.

bomber fleet, the smaller the expected percentage of planes to be lost and that the large fleet size should be used. As you recall from the headlines, this policy was adopted by the air commanders.

Training of Early OR Analysts

The majority of operations researchers who made these types of studies were scientists, usually trained in some discipline characterized by scientific objectivity and rigor, such as physics, biology, or other. In studying these new situations, these scientists recognized that an important part of their work was doing "research" to discover the relationships between the elements or objects of the operation or system under study. Hence, these scientists termed their work "Operations Research." However, if you examine it more closely now, you can see that, indeed, they did do research to discover principles, relationships, etc. governing a system or circumstance. But, they proceeded beyond discovering principles or underlying theory; they also "designed" a system or elements of a system so that the system as a whole would behave in some manner which they (on their side) considered best. The importance of this "design" aspect of their work should not be under-emphasized nor under-appreciated. Of course, they based their design upon an explicit, rational theory of the case which was complete with assumptions which they could test and with conclusions deductively obtained. The symbolic portion of the theory they termed a "mathematical model," although engineers and physicists more often use the term "ideal system."

"Methods Focus" of Early OR

After the war, the operations researchers asserted that their methods – and they emphasized their "methods" of research – were equally applicable to improving industrial operations. Thus, much of the early post-war work in industrial operations research was "methods focused." In any case, they made many useful contributions. In response to these contributions and to the apparent successes Operations Research achieved during the war, certain persons in General Electric decided that OR should be studied carefully to determine whether or not the claims made by the operations researchers were valid and, if so, how best this collection of techniques or concepts could be used within the Company. The essential findings of the study group were that, as a collection of tools, Operations Research offered a small but important refinement in methods of solving problems which often were resolved already by experience and intuition. This was substantiated by others, including Levinson (FORTUNE, November 1956) and myself (JOURNAL OF INDUSTRIAL ENGINEERING, 1953 and 1954). However, quite above and beyond the concept of Operations Research as a collection of methods, the study group recognized much greater potentialities of the broader research and design concepts as the basis for a particular kind of work with a definable and identifiable contribution to a business. At the risk of over-simplifying, it might be said that the essential findings of the study group were that a business enterprise as an operation or a collection of operations is amenable to rational idealization, analysis and design, just as a product, for example, is amenable to rational idealization, analysis and design. The important discovery of the wartime operations researchers was not that operations could be researched by scientific methods, but that they could be idealized and designed by conscious, rational processes, including scientific methods.

Discovering the Enterprise.

From this discovery arose the important concept of the "design of an enterprise" as the central contribution of OR. The special format through which the design is expressed is mentioned later. However, the design task is very challenging and it is not at all obvious as to how it can be performed rationally. I will consider this point in more detail later. Of immediate interest is that the concept leads to the usefulness of a special component of the business enterprise to design the enterprise, just as a component is needed to design the product. It has been found that this component is most effective if it is concerned with the design of the enterprise in the broad, in identically the same sense that the systems engineer in "hardware systems" is responsible for the design of the system in the broad, and not the design of the components of the systems in detail. This concept and need have been studied carefully and its implications recognized also by the managers of some of the Departments of the General Electric Company. (Each department is a highly autonomous enterprise.) Thus far, a significant number of departments of the Company have adopted such organizational components and, now, are doing work of this type under the name "Operations Research and Synthesis."

The implications from this innovation are quite important. Firstly, it is to be expected that the General Electric Company would be one of the earliest companies to recognize this new area of rational, conscious design work. It is virtually the largest employer (outside of the Government) of scientists and engineers. It should be expected, therefore, that it would recognize early the applicability of the scientific and engineering skills and methods, not only to the design of its product, but also to the design of its enterprises. As this idea is more fully developed, it is to be expected that industry in general will follow this lead and will learn how to use their scientific, managerial, and engineering talent and skills in this new manner.

Impact on Education

I expect that the impact on education of this innovation in enterprise design will be a mushrooming demand for manpower especially trained for this work. The uni-

versity, of course, will be called upon to supply the demand. Indeed, this demand already is being expressed now in the increasingly large number of requests for graduates who combine training in the sciences and scientific methods, in the institutions and concepts of business, and in the application of these methods to those institutions. A few universities have taken a leadership role in these regards, some of which are the School of Industrial Administration at Carnegie Institute of Technology; the Department of Engineering (Engineering Executive Program) University of California, Los Angeles; the Department of Management Science at Case Institute of Technology; the Department of Industrial Engineering at the University of Michigan; Department of Industrial Engineering, Columbia University; Operations Research-Systems Engineering Program in the Moore School of Electrical Engineering at the University of Pennsylvania; and several others.

In this same regard, in the American Society of Mechanical Engineers we have formed a special committee on "Operations Engineering" to pursue this same subject. The term "Operational Engineering" was selected as its name because, properly conceived "engineering" embraces the full spectrum of intellectual activities: creativity, research, development, design, synthesis and application. Thus, "Operations Research" as a term was considered deceptively restrictive of the Committee's intended sphere of interest and activity.

The Process of OR

The point I have stressed thus far is that the process of "Operations Research" is very similar to traditional engineering design work. Thus, our syllogism requires that we briefly review now the process of product design engineering. It involves, of course, conceiving the idea of a product, doing research – if necessary – to discover the principles or to discover what existing principles govern the operation of the product, as for example: field theory, conservation of energy, conservation of mass, laws of motion, or other. The particular intellectual processes are:

A. The conception of the idea for the product. The possibility that the product or object would be useful in affairs of the world must be brought to the conscious mind by some creative individual before it can be designed and constructed. The ability to conceive the idea for a new or modified product requires good understanding of the technical sciences which underly its operation, the feasibility of producing and designing the product, as well as its relative usefulness to society or its members.

B. The theory of the product or system so conceived. While he may not recognize it consciously, every engineer in designing a product or object develops a theory of that product. Without such theory he has no basis for reasoning about the object. This theory includes, as any other theory includes, a set of undefined terms, axioms, and specific theorems on the phenomena which underly the operation of the product or system.

In the "hardware" fields of engineering, the usual undefined terms include a mass, energy, temperature, force, etc. The axioms are the known physical and chemical principles, as well as the existence of a need for a product and of the processes and resources to produce it. The theorems are statements summarizing the reasoning on how a product or system would operate or behave. These are the "mathematical models" or "ideal systems" used to approximate a given product or system.

C. The design of the product is based upon the theories and is a concretion of those theories into a specific configuration and structure. The design specifies the components of the product, the inter-action of the components, the materials and properties of the components. The design usually is portrayed in some manner appropriate to the needs, such as drawings, specifications, processing instructions.

Subsequent steps in the total process would include: construction of the product, operating or using the product and obtaining "feedback" on the operation of the product so that the basic axioms, theorems or design can be corrected and the resultant design perfected ever further.

In the usual "hardware engineering" the knowledge and skills principally required in engineering a product are in physics, chemistry, engineering mathematics, engineering drafting, language and, recently but still in a relatively minor way, kinesthetics, human engineering, the economics of the product. Thus, most engineering curricula now emphasize the subjects which underly "hardware engineering." This emphasis is necessary and highly desirable, of course, for those engineers who will confine their careers primarily to product or hardware engineering.

Process of Enterprise Design in OR.

If the proposition that an enterprise or operation also can be rationally and consciously designed is true, then the process of enterprise or operations design can be shown to be consistent with the preceding process for engineering a product. On inspection, it is clear that the conception and design of an enterprise does follow the preceding process, although at present it often may be largely intuitive, just as 18th and 19th century hardware engineering was largely intuitive. However, OR has demonstrated that it is possible now to reduce the amount of purely intuitive design and analysis and to increase the level of rigor of this work so that it is comparable with the level of scientific rigor in the more developed fields of engineering. The simplified World War II examples illustrate the conception-theory-design sequence in operational engineering. Although the process as applied to an enterprise is essentially the same as applied to a product, the enterprise to produce a good or service is at least as complex as the good or service which it is to produce. Actually, of course, it is usually vastly more complex and intricate. Thus, the difficulty of designing the enterprise is at least as great as designing the product. For example, a business enterprise can be viewed as any and, simultaneously, as all of the following:

A. A set of physical facilities.
B. A financial investment and series of calculated risks.
C. A network and system of cash and value flows.

D. A network and system of material flows and material transformations.
E. A collection and structure of individuals, each with certain attitudes and abilities.
F. A decision and communication network and system.
G. A device for making decisions on use and allocation of scarce resources, i. e., on rationing and economizing.
H. An instrument for satisfying human material needs.
I. An instrument for satisfying human social needs.
J. The locus at which we individually and collectively practice our ethics, morals and religion.
K. An opportunity for psychological release of our aggressive propensities.

A business enterprise is each of these and it is all of these simultaneously and more; hence, the design of any enterprise must account for all of them simultaneously. In designing the enterprise, it is necessary to consider each aspect of the design from each of these perspectives and to assure that the concretion of the theory of the enterprise into the design is at least consistent with the needs and requirements in each of the other aspects. Thus, if an enterprise is designed with the care and precision with which a product is designed, the task is usually far more difficult.

Broad Scope in Application and Education

Of course, no single scientist, engineer or analyst alone could design an enterprise of any significant scale and scope. Rather, a group of persons with appropriate skills is necessary for this purpose. However, all persons participating in the analysis and design of an enterprise should have the breadth of perspective to envision whether any design decision in one area would have an impact in any of the many other aspects of the business. As can be gleaned from the list above, these aspects of an enterprise involve such diverse sciences and disciplines as economics, psychology and group processes, communication theory, decision theory, computers and electronics, etc.

Thus, Operations Research and Systems Engineering, as applied to business enterprises, require a wholly new level and breadth of training and understanding for adequate application and professional practice. They require an ability to discern and test relations and inter-actions in individual-machine-social or even economic systems, the ability to construct idealized models and/or theories of such systems for testing and selecting alternative designs and configurations, ability to reduce alternative to specific designs and to translate those designs into the appropriate information symbols for communication. The product engineer's communication techniques are primarily the engineering drawings and instructions and/or material and process specifications. The media for communicating and translating enterprise design include those of product engineering plus, at least, the following: verbalized policy and attitudinal statements, verbalized and graphic plans, organization hierarchical charts and networks with particular reference to information—decision networks and structures and to communication and information networks, decision criteria and rules, planning criteria, methods and rules, operating characteristics of facilities, operating methods and procedures. Obviously, therefore, the task of designing an enterprise and translating that design into these appropriate information symbols is a complex task and is as challenging as the design of any physical product or system, especially if it is designed with rigorous scientific methods, rather than by unaided intuition.

Examples of Designing An Enterprise.

The following is a brief description of one instance in which these concepts were used in achieving a new design of a business enterprise. The enterprise in this instance is engaged in the design, manufacture and marketing of a large apparatus equipment. The initial study was undertaken in order to improve one operation in that enterprise; that is, the product engineers were planning to use new methods and facility for certain design engineering computations. However, before they could use their new methods and facility with greatest advantage, it became clear that they should consider the possibility of changing the product from a custom-engineering product to one which would be engineered from standard components and with a standard or generic shape and configuration. The economic feasibility of the new facility depended upon the technical and economic feasibility of the change in the basic concepts and method of designing the product. Upon analysis of the total system, it was found that a change in product concepts, in turn, depended upon the technical and economic feasibility of many other changes, such as, the marketability of the redesigned product, its relative operational efficiency in the customer's system, the methods and economy of its manufacture, the methods of drafting its plans, the pricing and competitive policies which the redesigned products would allow or require, the advertising and sales promotion theme for the redesigned product, the changes in the basic manufacturing theory to adjust to anticipated changes in character of demand, etc. In addition, it was necessary to redesign methods and procedures affecting personnel so as to adapt to the human and social needs in the new environment with its implied changes.

Before the change in method of design computation could be made, it was necessary to interpret it and its derivative changes or implications in virtually all other operations of the enterprise so that the enterprise as a whole could be redesigned and restructured to accommodate the new operating characteristics of that one element of the enterprise. The redesign of the enterprise required a coordinated and integrated study of the business as a whole and of its components, such as marketing, manufacturing, engineering, advertising and personnel policies and procedures. For most effective redesign, the study group needed the ability to manipulate diverse concepts or principles, such as, in electrical engineering,

systems engineering, manufacturing engineering, market analysis, economic analysis, game theory or competitive strategy, communication and information theory, psychology and group dynamics. The output from their studies is a new design and structure of that enterprise—a new way of doing business. The overall design, in turn, is translated into the brick and mortar and the detailed design for all components of the enterprise by the members of those components, and in such manner that the design of each component is reliably consistent with the objectives and concepts of the whole.

The changes, initially induced by the introduction of the new computation method, resulted essentially in a wholly new design of enterprise and method of operation. Of course, not all redesigns are as dramatic. In most instances, the redesign to be effective must be continuous, just as the redesign of a product must be continuous if that product is to remain competitive. The need for evolutionary redesign of the whole enterprise may arise from any significant change in any of the components of the enterprise, in its product, in its technology, in its social or political environment, or other. The fruits of any innovation can be brought to society only when the system or enterprise has been designed to accommodate and to achieve that innovation. Hence, evolutionary design of the enterprise for innovation and change is designing for progress.

Suggestions for Educators

Although this is written primarily for engineering educators, it is to be noted that the operations researcher, enterprise engineer, or whatever he may be termed, is not the entrepreneur or entrepreneur-manager. He is a delegant of and, hence, responsible to the entrepreneur, just as other delegants also are responsible to entrepreneurs for the performance of their respective delegated function.

The educational question in regard to the enterprise analysis and design function discussed herein is not whether it is to be performed at all but whether it is to be performed ably and by persons especially trained for it. Already a special course has been established in the General Electric Company's Operations Research and Synthesis Consulting Service for training persons entering this kind of work. Of course, once the university-level Schools of Engineering and of Business Administration begin to offer integrated curricula in this new function, this special course may well be discontinued. It is noted that this course does not emphasize the techniques—linear programming, queueing theory, etc., which already are widely available—but, rather, the analysis and design function for which these techniques are but some of the important tools. I am confident that special training can and will be provided in the near future by university-level graduate schools of engineering and, possibly, of business administration through their curricula in the Management Sciences. My suggestions as to graduate study in preparation for this field are as follows:

Graduate training for whom?

Firstly, as S. F. Teele, Dean of the Graduate School of Business Administration, Harvard University, once said: "There are some tricks you can teach *only* to *old* dogs." The problem of enterprise analysis and design is, indeed, one which can be taught best to "old dogs," or those who personally have experienced the multiplicity of the conflicting demands and interests which converge on the managers and designers of enterprises and who, therefore, already realize the existence, difficulty and urgency of reconciling the demands in the design of the enterprise or its operations. Thus, graduate study in this field should be primarily for those who have at least some minimum amount of experience in business or industry and who are both intellectually and emotionally ready for such training. There is, of course, an opportunity to develop and offer undergraduate curricula for "young dogs" who may wish to enter this profession. That presents, however, a separate design problem and is not considered here.

Suggested Curriculum Content

Secondly, as to subject matter, I would hesitate to outline specific courses and numbers of study hours which would be desirable. Rather, I would suggest areas in which understanding and competence beyond those ordinarily provided by the more traditional engineering curriculum ought to be available. These lie, I believe, in five categories. They are not necessarily mutually exclusive nor complete. But they are suggestive.

A. Relevant sciences or bodies of knowledge on the phenomena of the real world. These would include:
   1. Physics
   2. Chemistry
   3. Psychology, Group Processes and Human Motivations
   4. Economics and Economic Geography
   5. Language, Thought and Communication

B. Relevant institutions or socially and individually imposed boundary conditions.
   1. Government and Political Institutions
   2. Social Control of Economic Activities
   3. History
   4. Citizenship and Responsibilities of Political and Economic Liberties
   5. Ethics and Philosophy
   6. Business and Economic Institutions and Practices

C. Relevant tools of formal analysis or symbolic systems for use in manipulating ideal systems.
   1. Usual Engineering Mathematics
   2. Logic and Boolean Algebra
   3. Linear Algebra and Matrix Theory
   4. Probability and Statistics
   5. Game Theory
   6. Calculus of Variations
   7. Measure Theory
   8. La Place Transform and Operational Calculus

D. Relevant constructs or the materials, process and systems of analysis as applied to specific phenomena
   1. Usual Engineering Course plus
   2. Information and Communication Theory, especially as related to Man-Man and Man-Machine Communication Systems

3. Economic Analysis (Qualitative and Quantitative) essentially as Business Ecology
4. Systems Theory and Network Analysis
5. Information Processing Equipment

E. Phenomena of enterprise or the phenomena characteristic primarily of organized human endeavor.
1. Individual and Group Decision Processes and Group Structuring
2. Organization Theory in Individual, Social, Man-Machine and Group-Machine Systems
3. Decision Theory and Competitive Analysis
4. Creativity and Idea Propagation
5. Individual and Group Motivations
6. Ethics, Value Theory and Choice
7. Program Planning and Testing

"Cases" for Idiographic Integration

The above constitute, according to my experience both in industry and academia, the intellectual equipage for professional work in this field. It is, however, only the point of departure and not the goal. Finally, and importantly, the student should be given concrete experience and competence in the application of these basic sciences to the design and structuring of operations and/or enterprises. I believe this is done best through vicarious and/or direct experience in these functions. Such experience may be gained through appropriate case problems, externships or on-the-job supervised problem-solving. In all of these the student should be required to "solve" or design an enterprise or operation thereof whose complexity and scope are sufficient to challenge his abilities. His studies and experiences in these should be made meaningful by careful instruction and supervision, by a staff of instructors operating as a well coordinated team with each member thereof providing the competences or insight in one or more of the various disciplines which are necessary to solve such problems. The instructional team to administer the studies and the use of general principles to resolve such problems appear to be a significant departure from the present case method of studying and training in problems of enterprise design and operation. That is, each case, as suggested here, would not be an ad hoc collection of circumstances for which no general principles or tools of analysis would be demonstrated for solving the problem in a definitive kind of way. Rather, it would represent a unique, but illustrative, collection of circumstances to which general principles and methods could be applied, leading to the rational design of an enterprise or operation, thereof, in the same manner that "hardware" engineering problems can be "solved" to lead, usually, to a design of a product or system for specified purposes.

Humanities: New Content in the Engineers' Work

I wish to make particular note that the concepts and principles implied above, in humanities, e. g., ethics and philosophy or citizenship and responsibilities of political and economic liberties, are as much a part of the intellectual paraphernalia and design criteria the enterprise or operational engineer uses as is, say, integral calculus or thermodynamics. This, I believe, is a view different from that expressed in the recent ASEE report on Engineering Education wherein humanities are conceived as providing essentially an extra-professional cultural background for the engineer. My point is that the enterprise engineer uses, or is guided by, all of the concepts in the above list as may be appropriate to the specific task at hand; in many design tasks good citizenship, psychology, or ethics is more important than good calculus in achieving the optimum-solution or design.

The preceding recommendations are intended primarily for Engineering Schools where already the student is trained and the faculty is experienced in methods of science and in the analysis and design functions. The range of objects or systems treated in this manner by engineers and engineering schools recently has expanded to include design and operation of more complex man-machine systems. Hence, my suggestion as it applies to engineering schools is merely that there is a need and an opportunity for those schools to extend the range to include those systems called "enterprises" as well as portions of the operations therein. My remarks are not intended for Business Schools where usually the students are not trained and the faculty is not experienced in the methods of science and in the analysis and design functions. These schools present a different problem and opportunity which are handled best, I believe, by a new department which I would call a Department of Management Sciences.

Challenge for the Future

From a broad social perspective, the development of operational, or "enterprise" engineering curricula which would combine competence in the fields necessary to devise and design most efficient enterprises consistent with the important responsibilities of the enterprise in serving the diverse needs of society could lead to important steps for strengthening and enhancing our social system of individual liberties and free competitive enterprise. This enhancement would come from greater assurance that individual and social needs are better satisfied through the structure and design of the total work environment and that social and material progress is achieved effectively and harmoniously through continuous redesign of enterprises to effect social and technical innovations. These, of course would seem to be worthy endeavors of the university level of Schools of Engineering or the Departments of Management Science in the Schools of Business Administration.

REFERENCES

(1) Barish, Norman N., "New Undergraduate Curriculum in Industrial Engineering" *Journal of Industrial Engineering*, Vol VII, No. 5 September 1956.

(2) Brothers, LeRoy A., "Education for Operations Research", *Operations Research*, Vol 4, No. 4, August 1956.

(3) Salveson, M. E., "Suggestions for Graduate Study in Operations Research and Systems Engineering" presented at Annual Meeting ASEE, Ames, Iowa, 1956.

Some Statistical Considerations in Work Sampling

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Work sampling is significant in that it represents the beginning of recognition of the problem of work measurement as essentially one of sampling, estimation and prediction. It marks the beginning of the use of statistical methods to cope with the variability inherent in work measurement.

The usefulness of a work sampling estimate depends upon the properties of accuracy, precision and "applicability". However, only precision has been considered in most of the previous literature on work sampling and this always based on the simple binomial model. Other models are reasonable and desirable, particularly in the case where it cannot be assumed that observations are independent.

Although all work measurement is actually a sampling process the term "work sampling" is generally taken to refer to a relatively recent development in work measurement. Work sampling was introduced in this country about ten years ago (2) and has achieved considerable importance in recent years. The mechanics of the technique and the description of different applications have been widely documented in recent time-study textbooks and the various technical journals (1). By way of brief synopsis, work sampling has two distinguishing characteristics and has been applied to two broad classes of problems.

The technique is characterized by the use of intermittent sampling over a protracted interval of time (as opposed to conventional time study which is of a continuous nature over a relatively short period of time), and by the use of qualitative observations. An observation consists of a description of the state of the activity concerned at a particular instant of time. No quantitative measure (e.g. stopwatch timing) is required.

Most of the applications of work sampling can be classified as either the estimation of the *proportion* of time in which an activity is in a particular state, or the study of the activity of a *team* of men, or machines. The estimation of the proportion of machine down-time was the problem that led to the origination of work sampling (3) and much of its application since has been to similar problems. In fact, the technique is often called "ratio-delay" study although by now its use is considerably broader than that name would imply.

Advantages of Work Sampling

A significant advantage in effectiveness is claimed for work sampling over alternative methods of producing the required information. Differences in effectiveness—the relationship between the quality of performance and the cost of the process—are difficult to make precise, largely because the quality of performance stubbornly resists quantification. For the first type of application—that of determining a proportion of time devoted to some particular activity—work sampling must compete with the all-day time study or production study and with apocryphal allowances that evolve from intuition or years of bargaining. A saving of from 50 to 75% of the cost of an "equivalent" production study is claimed for work sampling (1, 2). The accuracy of this estimate is problematical. In the first place a reasonable definition of an "equivalent" production study has not yet been offered. Moreover, work sampling undeniably requires a longer time to arrive at an answer than does a production study. For the work sampling study to cost less implies that the observer be able to profitably utilize his time between observations. The extent to which this frequently interrupted work time can be effectively used depends upon the particular sampling plan, the type of alternative work available, and in large measure, upon the individual observer (and his supervision).

The only competitors to work sampling for the second type of application—the study of team activity—are simultaneous production studies by more than one observer and the after-the-fact analysis of accounting and production records. The former is so prohibitively expensive that it is rarely used; the latter yields only an incomplete type of information that must be considered a supplement to direct measurement rather than measurement itself. Hence the superiority of work sampling in this area is largely uncontested. The major question is not which method of measurement, but whether or not measurement itself is worthwhile for this type of activity.

Statistical Work Measurement

Perhaps as important as any achievement or advantage

of work sampling is the fact that it represents the beginning of recognition that work measurement is essentially a problem of sampling, estimation and prediction. Work sampling marks the beginning of the use of statistical methods to cope with the variability inherent in work measurement. It does not represent a solution to the problem, or even to a small part of the problem, but only a beginning.

There is a fundamental dichotomy between work measurement and the measurement of physical quantities. Work measurement deals with an extremely fragile substance—one that is very likely to be altered in its dimensions simply because it is being measured. Work sampling differs from other types of sampling in that the measurement associated with a particular element of the population may be substantially altered simply because that element was selected for observation. Other areas of measurement encounter measurement errors, and other areas of sampling experience difficulty in eliciting true responses, but it is doubtful whether either encounters as strong and direct a motive for deliberate deception as does work measurement. Work measurement must often operate in an atmosphere of conflict in which at least one party to the process feels that accurate measurement is diametrically opposed to its own best interest. These difficulties require, rather than preclude, the use of statistical methods.

Accuracy, Precision and Applicability

There is lacking in much of the literature on work sampling any explicit recognition of the difference between the *accuracy* and the *precision* of an estimate.[1] Moreover, if the population concerning which inference is to be made is defined to be the total period of time during which the study is performed, then a third characteristic becomes relevant to the usefulness of the estimate. Since the utility of the estimate lies, in general, in its *applicability* to time periods other than the parent population, it is important to ask whether the population upon which the estimate is based is similar to, or representative of, the longer period to which the estimate is to be applied.[2] It is quite possible to have an estimate that is good with respect to the parent population be useless since the conditions that existed during the period of measurement no longer obtain.

The literature on work sampling would lead one to believe that given a statement of the error that will be tolerated in the estimate the procedures described will specify a plan that meets that requirement. This is not true. The given procedures concern only the precision of the estimate. They specify the number of observations that would be required to reduce the sampling variability to the required confidence interval. They do not consider the accuracy—i.e. the amount of bias—of the estimate. Contrary to widespread impression *accuracy* is not improved simply by increasing the number of observations. A constant bias is unaffected by an increase in the number of observations and actually becomes relatively more important as the sampling variability is diminished. Moreover these procedures overlook the important and difficult problem of assessing the applicability of the estimate to time periods other than the parent population. The overall problem of specifying a procedure that yields a useful estimate and a limit on the error of the estimate is very difficult and unfortunately not amenable to presentation by a neat mathematical formula.

Bias can exist in an estimate due to the use of a biased estimating formula. In some cases such a formula is advantageous in spite of the bias it introduces because of other desirable properties. Far more important in the case of work sampling is bias that is inadvertently introduced in the design and the execution of the sampling process. This bias is not necessarily reduced by increasing the number of observations and it cannot be detected or eliminated by manipulation or analysis of the data. It can be detected only from information outside of the sample. It can be prevented only by the proper design and execution of the sampling process.

The precise definition of the population to be sampled, the definition of the different states of activity, and the method of selecting the observation times are all possible sources of bias in the design of the plan. There are many possible sources in the execution. To the extent that the worker can anticipate the time of observation and is able to alter the state of activity that will be observed, work sampling is susceptible to a very serious amount of bias. The observer is similarly capable of influencing the results of a study, although perhaps unintentionally, if he has latitude in choosing the moment of observation or if there is any ambiguity in the definition of the various states of activity.

The most appropriate methods of detection depend upon the suspected source of bias. Those suggested here are means of checking methods and personnel rather than individual applications of work sampling. At that, they are only partial checks. The extent to which the observer contributes to bias can be investigated by having two or more observers perform simultaneous studies on the same situation. The contribution of individual workers or of elapsed time can similarly be evaluated by multiple studies. A simple three factor experiment (observer, worker, time) could be readily used to investigate the properties of work sampling as practiced by certain personnel in a particular environment. There is also the possibility of simultaneous and sequential application of work sampling and con-

[1] *Accuracy* is a measure of the degree of *bias* in measuring. *Bias* is the amount by which the long run, observed mean value of a set of measurements differs from the "true" value of the quantity. *Precision* is a measure of the reproducibility of the measured value of a given quantity without regard to the "true" value of that quantity. It is a comparative index based on the variance of a set of measurement of a given quantity.

[2] If the population is defined to be the longer period to which the estimate is to be applied the terminology is changed but the problem remains the same.

tinuous time-study to the same job. This would provide a check on the sampling variability introduced by intermittent sampling as well as on the ability of the worker to influence the results of such a study.

The question of applicability of the estimate can be rephrased to a matter of determining a period for study that is representative of the period over which the estimate is to be used. While it is virtually certain that conditions will not remain identically the same over any extended period of time, it is still worthwhile to avoid selecting a period for study that includes some unusual circumstance.

Methods and criteria for selecting the length of study are almost completely neglected in the literature on work sampling—yet this selection is at least as important as the determination of the number of observations. There are admittedly some autonomous influences on the length of study over which the analyst has little control. The most basic of these is the necessity of producing some sort of answer before a certain deadline. Another frequently encountered is the limited duration of the activity being studied. Other restrictions can involve matters of established practice or policy, perhaps as written into a union contract.

In general, the period of study should be at least as long as the longest period of any cyclical behavior of the characteristic being studied. Such cyclic behavior could depend upon clock time, calendar time, physical characteristics of the activity, or on policy or procedural requirements—such as the frequency of inspection or maintenance activity. For example, if there is any *a priori* basis for suspecting that the pattern of activity is different on different days of the week, the period of study should obviously not be less than a full week.

The adequacy of the period of study can be evaluated in part by the comparison of different portions of that period. A convenient method of doing this is the use of the control chart concept. This is readily applicable, particularly where a stratified form of sampling has been used. A worthwhile check on the selection of the length of study is an occasional over-long study or a separate check study.

One approach to the problem is the use of a two-level or two-stage sampling plan. Relatively short periods of study are first selected at random, then these periods are sampled as before. This would involve a prohibitive delay in obtaining results for some applications, but for important studies whose findings will be perpetuated by contract—such as widely used delay allowances—this type of sampling should be seriously considered. Sampling in this manner would provide an estimate of the variability between periods as well as within periods.

Precision and the Binomial Model

The characteristic of precision is more tractable to mathematical expression than either accuracy or applicability. By assuming the appropriateness of a particular mathematical model for the activity being studied one can use an expression for the variance of an estimator as a measure of the precision of the work sampling estimate. This assumption of the appropriateness of a particular model is implicit in all of the formulas for the determination of the necessary number of observations that are found in the literature. The various authors uniformly assume the simplest possible model—that the probability of finding the activity in question in a particular state is the same throughout the period of study. Under this assumption the relative frequency with which X of the n observations are to be found in a particular state when the probability of finding any one observation in that state is "p" is given by the binomial distribution:

$$f(X/n) = \frac{n!}{X!(n-X)!}\, p^X (1-p)^{n-X}$$

where $0 \leqq p \leqq 1$

X is an integer; $\quad 0 \leq X \leq n$

$n!$ is n factorial—the product of the n factors $n, (n-1), (n-2), \cdots, 2, 1$.

$0!$ is defined to be 1

For this simple binomial model the sample proportion (X/n) is an unbiased estimator of the probability p—the average of the sample proportions from an infinitely large number of samples from the same population would be equal to the probability p. This means that the estimating formula does not introduce a bias; it does not ensure that the sampling procedure is conducted in a manner that precludes bias.

The variance of the sample proportion, a measure of its precision as an estimator, is given by the following expression:

$$\text{Var}\ (X/n) = \frac{p(1-p)}{n}$$

The probability p is, of course, unknown. An approximation to the variance is obtained by substituting for the unknown p its estimator, the sample proportion (X/n).

A Model for Stratified Sampling

It should be immediately obvious that many applications for work sampling involve situations where it is not reasonable to postulate that the probability of finding the activity in a given state remains constant throughout the period of study. For example, it seems quite unlikely that the proportion of delay time for a machine tool is constant throughout the day. The beginning and ending periods of the shifts will, in all likelihood, contain a greater proportion of delay time than the body of the shifts. In the study of a warehouse crew, periods associated with a shipment departure or arrival might well exhibit a different pattern of activity than the remainder of the day. Some complication of the model is required to cope with this situation. One such modification is to consider the population to be divided into periods, or strata, in each of which the probability is constant. The following notation may be used:

f_i is the fraction of the total length of the study represented by the ith period or stratum

p_i is the probability of finding an observation in the ith stratum in the particular state under consideration

n_i is the number of observations taken in the ith stratum

X_i is the number of observations in the ith stratum for which the activity was in the particular state under consideration

The overall proportion of time represented by the particular state of activity in question is given by a weighted average of the strata probabilities:

$$\hat{p} = \sum_i f_i p_i$$

An unbiased estimator of this overall proportion is:

$$\bar{P} = \sum_i f_i \frac{X_i}{n_i}$$

The variance of this estimator is given by:

$$\text{Var } (\bar{P}) = \sum_i \frac{f_i^2 p_i(1 - p_i)}{n_i}$$

If the allocation of observations among periods is proportional to the length of the period these expressions simplify to the following:

$$\bar{P}' = \frac{X}{n} \qquad \text{where } X = \sum_i X_i \quad \text{and} \quad n = \sum_i n_i$$

$$\text{Var } (\bar{P}') = \frac{1}{n} \sum_i f_i p_i(1 - p_i)$$

This variance attains its maximum value when all of the p_i are equal:

$$\text{Max. (Var } (\bar{P}')) = \frac{p(1 - p)}{n}$$

where p is the common value of the p_i. This is the same as the variance for the simple binomial model. The conclusion is that proportionally-allocated stratified sampling is always at least as precise as the simple random sampling that is appropriate for the binomial model. When all of the p_i are equal, then the variance of the estimate based on the stratified sample is the same as that based on the simple random sample. When the p_i are not all equal, the estimate based on the stratified sample has smaller variance (assuming the same total number of observations.) This means either that it is more precise or that it is capable of obtaining the same precision with fewer observations. However, if the allocation of observations among the strata of the population is other than proportional to the length of the strata it is possible for the variance to be larger than that of a simple random sample.

An illustration will serve to demonstrate the improvement that can be obtained by the use of stratified sampling. Consider the problem of estimating the amount of idle time of the attendant of the tool crib in a machine shop — perhaps in preparation for a relayout of the crib, or the addition of a helper, or in the establishment of an incentive wage system for certain indirect labor jobs. If the overall proportion of idle time is 40%, but for a period that consists of the first hour in the morning and the last hour in the afternoon of an eight hour day, there is only 5% idle time as the machine operators check out and turn in the day's tools and gages, the estimate of the proportion based on a sampling plan that separated those two hours and allotted to them one-fourth of the total number of observations would have $\frac{5}{6}$ the variance of the estimate based on a simple random sample with the same number of observations. Alternatively, the same precision could be obtained with 17% fewer observations. An additional improvement could be obtained if one could estimate in advance about what the values of p_1 and p_2 would be and distribute the observations between the two periods in an optimal fashion that minimizes the variance. In the example cited this would allocate 12.7% of the observations to the shorter period of 25% and the resulting variance of the estimator would be 77% of the variance of the estimator based on a simple random sample with the same number of observations. The improvement over the proportionally-allocated stratified sample is not great and since one cannot estimate the exact values of p_1 and p_2 in advance as was done here it is doubtful whether this so-called optimum allocation is worthwhile. Another drawback to its use is that if the preliminary estimates of p_1 and p_2 are too far off, it is possible to specify an allocation of observations that will cause the estimate to be less precise than that based on a simple random sample.

The advantage obtained through stratification in sampling for proportions is at best modest when compared to what can be gained by stratification in other types of sampling. However, it is often the case that the population is broken down into shorter periods for administrative reasons and stratified sampling is performed although the simple binomial model is presumed to be applicable. Particularly when this is true, it is pointless to ignore the advantage provided by stratification. The greatest benefit from stratification can be obtained if the strata are constructed to have as different values of the proportion in question as possible. These strata can be further subdivided as an administrative convenience if desired, and this will contribute further to increasing the precision of the estimate if there are, in fact, differences in proportion between these subdivisions.

A Model for Non-independence

When there are m machines, or m members of the team, it is common practice to take observations m at a time so that the required total of n observations can be accumulated in n/m trips. This is a reasonable procedure, and in the case of some team studies, an essential one. Unfortunately, in a great many cases, it vitiates the assumption of independent observations required for either the simple binomial or the stratified model. For observations to be

independent requires that knowledge of one observation give you no additional information about what to expect on any of the other observations. Obviously, in many cases where observations are collected in groups this requirement will not be satisfied. The discovery that the first of a number of machines is shut down will increase your expectation that the next machine will also be shut down since there are many causes of delay that affect more than one machine. In the same way, the discovery that one man of a group is not working because he is engaged in conversation increases your expectation that at least one other man will be similarly occupied. The application of the binomial model to a situation that exhibits this kind of non-independence will produce what can be a very considerable understatement of the variance of the estimate.[3]

A model appropriate to this situation would consider the fundamental unit of the population to be the state of activity of a block of m machines, or m men, at a particular instant rather than of a single machine or man. The measurement associated with the jth observation is X_j — the number of the m machines or men in the particular state at a given instant. X_j takes on one of the values $0, 1, 2, \cdots, m$. An unbiased estimate of p is given by the average of the observed values of X_j/m:

$$P = \frac{\sum_j \frac{X_j}{m}}{n} = \frac{\sum_j X_j}{n} = \frac{X}{n}$$

The estimator reduces to the overall sample proportion, just as for the simple binomial model. However, an estimate of the variance of the estimator is given by:

$$\text{Est.Var}\,(P) = \frac{m^2}{n^2} \sum_j \left(\frac{X_j}{m} - \frac{X}{n}\right)^2$$

The X_j and X are not known in advance, of course, so that a preliminary estimate and subsequent recalculation are necessary, but then, the same is true for the use of the binomial model.

Systematic Sampling

All of the models discussed thus far have been predicated upon the assumption that the times at which observations are to be taken are selected at random. This requirement is not satisfied by irregularly spaced observations — some formal effort at randomization is necessary. The human being has frequently been exposed as a notoriously poor randomizing device, and an offhand selection of the times for observation may have very serious and unsuspected effects on the results of a study.

A great deal of work sampling is performed using some form of systematic sampling in which observations are taken at regular intervals of time. The chief advantage of this method is that the time between successive observations is always the same. It is often easier to use the observer's available time profitably when the intervals are of equal length, rather than when they have lengths which vary at random. The most obvious use of this time is to simultaneously carry on other work sampling studies, each with the same period between observations. It is impossible to synchronize the work of many separate studies when the time of observation for each is selected at random.

If there is no cyclic behavior present in the phenomenon under study, systematic sampling is acceptable, and certainly advantageous from an operating point of view. However, in a large majority of applications of work sampling there would appear to be strong *a priori* reason to expect periodicity. This is in part due to physical characteristics of the activity, but even in the absence of this, it would exist due to the fact that the sampling is done over time and the times of day recur with cyclic regularity as do the days of the week. Thus if the phenomenon is at all dependent upon time, it will have some tendency toward cyclic behavior. It should be obvious that if the regularly timed observations of a systematic sampling plan should be "in phase" with some periodic delay, work sampling will produce an absurd estimate of the proportion of time represented by delays. Moreover the worker is often quite capable of contributing materially to a synchronization of his work with the sampling plan and is aware of the fact that it may be in his best interest to do so. This makes the use of systematic sampling at best a hazardous procedure for work sampling since it renders the process particularly susceptible to bias. The determination of precision is also affected since the models previously discussed do not, in general, apply when systematic sampling is used. Although the determination of the variance of an estimator based on a systematic sample has received some attention in the sampling literature the problem is a very difficult one and no general result has been given.

[3] Although it is theoretically possible for non-independence to cause overstatement of the variance the type described — which is the type commonly encountered — causes understatement.

REFERENCES

(1) Malcolm, D. G. and L. L. Sammet, "Work Sampling Applications", *Journal of Industrial Engineering*, Vol. V, No. 3, May 1954, pg. 4.

(2) Morrow, R. L., *Time Study and Motion Economy*, Ronald Press, N. Y., 1946, chapter 16.

(3) Tippett, L. H. C., "Statistical Methods in Textile Research, Uses of Binomial and Poisson Distribution in Textile Research, A Snap Reading Method of Making Time Studies of Machines and Operatives in Factory Surveys," *Textile Institute Trans. Journal*, Vol. 26, 1935.

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A Basic Approach to Cargo Handling Analysis

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The purpose of this paper is to describe a method of cost analysis which has heretofore not been systematically applied to the marine field. The method discussed, the time study operates in a zone midway between machines and men, between science and art. It is believed to be of interest to the members of AIIE because the application of time and motion principles to marine cargo handling analysis can lead to a better understanding of the nature of cargo handling costs and how they can be reduced.

Beginning in the 1890's with Frederick Taylor's "A Differential Piece Rate" and continuing with the advances made by Barnes, Carroll, the Gilbreths and many others, the "science" of time and motion study has been continuously developed and broadened until it is now a recognized "tool" of management in most industries involving repetitive tasks. At the same time its social foundations have matured to the present level where both managements and labor unions have come to appreciate its valid uses as well as its limitations. Time study has at last been recognized for what it is: just one more device for analyzing costs, which like all other devices may or may not assist in improving production efficiency depending on whether or not it is used properly and fairly.

Keeping in mind these limitations as to the effectiveness of time study, it is considered that our shipping industry might benefit from its application to marine cargo handling operations. While these operations are far from being as rigidly controlled and uniform as those of a typical production-line establishment, they do consist of repetitive or cyclical tasks which can be time-studied and which follow generally similar patterns along the waterfront. The ships, fork trucks, dock tractors, palletized and containerized units the basic tools of marine cargo handling are manufactured, sold and used on a nationwide basis. There are many similarities between the cargo handling methods of steamship company "A" in Seattle and those of company "B" in Boston. This is not to suggest that specific time-study data is necessarily applicable to all operations, but rather that we are dealing with a problem nationwide in scope, generally similar in its components and with a suggested method of analysis which is therefore generally applicable.

The approach outlined in this paper is of particular interest at present because of the many efforts which have been made since World War II to cut cargo handling costs. These efforts have generally revolved around new mechanical devices: new ship designs, new terminal designs, new winches, rigging arrangements and hatch covers, new packaging arrangements and improved fork trucks, tractors, cranes and the like. At the same time it has been recognized that the ultimate success of these new devices depends equally upon how well they are used together as well as how they perform individually. Terminals, ships, containers—all equipment used in moving or storing cargo forms an interlocking chain. An improvement of one link in the chain may not necessarily improve the whole. On the other hand, substantial economies may sometimes be effected simply by changing the *way* in which handling devices are used together, without involving any expenditures for new equipment.

Present cargo handling costs can and must be reduced. Management needs a measuring stick, a form of analysis to find out whether existing methods can be overhauled or if new methods will pay for themselves. The purpose of this paper is to suggest a basic approach to marine cargo handling analysis and to point out ways in which it can be used.

Cargo Handling Cycles

A typical general cargo loading operation includes the following cycles directly affecting steamship line operating costs:

(a) Local delivery cycle	Cargo delivered to transit shed by truck, railroad or trans-shipment vessel
(b) Dock gang cycle	Cargo re-stacked on pallets or board slings
(c) Apron delivery cycle	Cargo drafts moved to loading apron via dock tractors or fork trucks
(d) Ship's gear cycle	Cargo drafts hoisted into hold
(e) Hold cycle	Cargo stowed in ship's hold by hand or using stacking equipment

Each of the above cycles is a completely repetitive

operation, constantly returning upon itself—hence the term cycle. Although the above list is typical there are of course many variations in the number and kind of cycles used in loading and discharging cargo. The essential point is that all cargo is handled by means of cyclical steps which can be separately analyzed.

With the exception of cycle (a) above—the local delivery cycle—a typical cargo loading operation comprises all the above cycles working at the same time, the drafts of cargo moving from one cycle to the next more or less continuously. Since stockpiling between cycles is rarely used, the speed of each succeeding cycle is directly dependent upon those of the other cycles.

Each of the cycles has a characteristic working speed of its own, and when all cycles are working together, each one dependent upon the preceding and following cycles for delivery and pickup of the cargo drafts, the speed of the slowest cycle governs the overall speed of the entire operation. A useful comparison is that of the chain, which is only as strong as its weakest link.

In actual stevedoring practice, the situation is constantly changing as different cycles are slowed down or speeded up. Each cycle works within a framework of variables which govern its characteristic speed at any given mom t. For instance: the speed of the apron delivery cycle depends on the roundtrip distance between the storage pile in the transit shed and the apron loading point. This cycle is also affected by the aisle widths, condition of pier decks, stability of the loads, etc. Each of the other cycles is likewise governed by its own particular set of variables, which act at different times in different degrees. The net effect of all these variables, therefore, is to create actual cargo handling operations which are continually shifting as one cycle—then another—momentarily limits their speeds.

This dynamically changing nature makes the analysis of handling costs, either through statistical cost keeping systems or by casual observation of the actual operations, extremely difficult. The statistical approach tells us what has happened in the past, but conceals too many variables to justify its validity in predicting what could or should be expected of future operations. Practical experience and intimate contact with day-in, day-out operations can develop in management a sound grasp of the relative speeds of different cargo handling cycles, but fails to develop rational data expressing quantitatively the effects of different variables on productivity. As a consequence, management's task in evaluating the worth of new equipment or methods is hampered by the lack of accurate information.

A more effective way of analyzing cargo handling is through the use of time and motion studies. By time studying actual cycles it is possible to determine their net working speeds as though they were working alone, and so to ascertain which of the various cycles is the slowest under the prevailing conditions, and by how much it is holding up the other cycles.

Another use of time-study information is that it enables management to set up standard cycle speeds which can be used as a comparison with actual performance and which can also be used in predicting the anticipated productivity of proposed new combinations of cargo handling cycles.

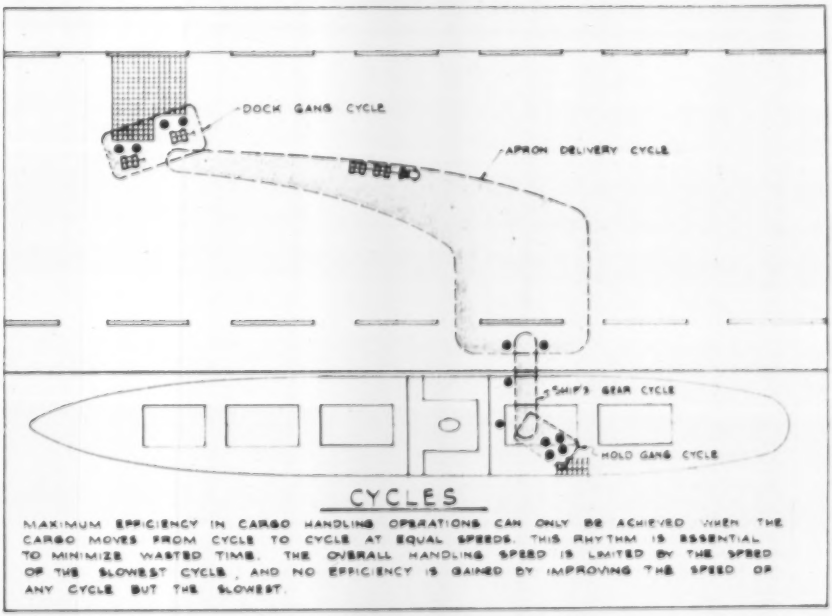
DOCK GANG CYCLE
APRON DELIVERY CYCLE
SHIP'S GEAR CYCLE
HOLD GANG CYCLE
CYCLES
MAXIMUM EFFICIENCY IN CARGO HANDLING OPERATIONS CAN ONLY BE ACHIEVED WHEN THE CARGO MOVES FROM CYCLE TO CYCLE AT EQUAL SPEEDS. THIS RHYTHM IS ESSENTIAL TO MINIMIZE WASTED TIME. THE OVERALL HANDLING SPEED IS LIMITED BY THE SPEED OF THE SLOWEST CYCLE, AND NO EFFICIENCY IS GAINED BY IMPROVING THE SPEED OF ANY CYCLE BUT THE SLOWEST.

Fig. 1. Cycles

Making the time study

This paper will not attempt to cover all the details of time-study procedures, since there are a number of publications available dealing with the general subject. Some of the highlights and some problems peculiar to marine cargo handling analysis are outlined below.

The procedure generally consists of timing a particular cycle for ten or more successive round trips (ten readings will usually suffice).

(a) *Fixed Conditions:* The time-study must be taken while the cycle under observation is working under fairly fixed conditions. During the timing the type of cargo, its location in the transit shed or ship's hold, the height to which it is tiered, and other variable factors all must be kept constant insofar as they affect the cycle speed. This is sometimes difficult in actual marine practice, but can be done if the cargo lots are large enough to warrant analysis.

(b) *Cycle Elements:* Before commencing the actual timing, the cycle should be closely analyzed and its separately defined steps or elements listed on the time study sheet in their order of occurrence. For instance: an apron delivery cycle using a fork truck may comprise the following elements:

(a) Enter storage bay, travel 10 feet to storage pile, pick up loaded pallet, back out to aisle
(b) Travel 200 feet to apron, deposit loaded pallet
(c) Pick up empty pallet, travel 150 feet to pallet storage, stack pallet
(d) Return 75 feet to storage bay entrance.

This "breakdown" of cycles into their component elements is helpful in subsequent analysis and codification of the data obtained, in that like elements can be directly compared even though obtained from entirely different overall cycles. Also the elemental breakdown provides a direct means of establishing the time consumed by waiting periods or other non-productive elements.

(c) *Stopwatch Procedure:* When the elements making up the cycle have been listed the actual timing can be commenced.

(d) *Waiting Periods:* In timing cargo handling cycles it will often be observed that a portion of each cycle is taken up with waiting for a preceding or succeeding cycle. This is particularly true in marine work because of the multiplicity of variables, mentioned above, which cause wide fluctuations and consequent unbalance of the cycle speeds.

For instance, in the apron delivery cycle above, it may be observed that during the period under observation the fork truck operator is regularly required to wait in the transit shed while the dock gang finishes stacking the cartons from the dock floor onto the pallet. The apron delivery cycle is in effect being held down to the speed of the slower dock gang. If this waiting period occurs often enough to be of any consequence it should be shown on the time-study sheet as a regular element along with the productive elements already listed, and so timed.

It may also be observed that each cycle is further taken up with occasional minor stoppages or waits, as the men stop to receive instructions, adjust their equipment, etc. Such miscellaneous non-productive periods are accounted for by setting up a "miscellaneous waits" category on the time-study data sheet and recording the accumulated time at the start and completion of each such period as it occurs.

It should be parenthetically noted at this point that the act of making a time-study does not of itself constitute a passing of judgment on the personnel being observed or the methods being used. Time study as such is merely fact-finding. By the same token, the use above of the words "non-productive periods" does not imply a critical attitude towards such periods. The term is rather used in its direct application as simply denoting time expended without resulting in a physical movement of the cargo through the cycle. It is of course recognized that many "non-productive" periods are in fact necessary to do the job or are beyond the control of the cycle personnel.

(e) *Rating:* The purpose of the time-study is to arrive at the average cycle working time required by typical well-trained workmen moving at an average level of effort or "pace". It is necessary therefore, that the time-study analyst rate the actual workmen under observation, to establish their relationship with the above norm. This rating procedure is essentially an act of judgment on the part of the observer. It is the *only* part of the time study involving judgment rather than factual data. As applied by an experienced time study analyst this can be quite equitable.

Figure 2 is a sample Time Study Data Sheet, completely worked out to illustrate the time study procedure.

Balance allowances will be found to vary considerably from cycle to cycle. In any particular multicycle operation the greatest balance allowance will of course be found at the fastest cycle and the smallest at the slowest or limiting cycle. Balance allowances in marine cargo handling cycles have been observed as high as 528% and as low as 2.4%; they never quite reach zero even with a limiting cycle. Indeed, there is no reason why the balance allowance should reach zero, since some time must always be given over to relief, instruction and repair periods. Also, even limiting cycles are sometimes held up by faster cycles because of non-simultaneity of arrivals at their contact points. In highly regularized production line establishments such as automobile assembly lines

TIME STUDY DATA SHEET

Ship (C3) Pier -- Date (Saturday AM, Sunny & Clear)

Cycle Observed Hold Gang discharging from No. 2 Upper Tween Deck (in Stbd. Fwd. Wings)

Commodity Data Crated goods - each abt. 23" x 28" x 30" Average Weight per Crate = 192 lb.

4 Crates per pallet draft Average Weight per Draft = 0.384 short tons

Element	Rtg	1	2	3	4	5	6	7	8	9	10	Total	Act. Avg.	Rtd. Avg.
Manhandle crates onto pallet	100	(58) .58	(45) 4:06	(50) 7:27	(70) 13:28	(56) 18:22	(45) 23:20	(148) 28:10	(127) 40:27	(97) 43:46	(103) 49:19	799	79.9	79.9
Place Tie line around draft	110	(19) 1:17	(42) 4:48	(29) 7:56	(26) 14:20	(17) 18:39	(57) 24:17	(27) 29:39	(14) 40:41	(29) 44:15	(11) 49:30	271	27.1	29.8
Wait for ship's gear	--	(57) 2:14	(40) 5:28	(185) 11:01	(121) 16:21	(168) 21:27	(15) 24:32	(18) 29:57	(19) 41:00	(118) 46:13	(0) --	741	74.1	--
Place slings under loaded pallet, assist in hoisting clear	100	(20) 2:34	(21) 5:49	(16) 11:17	(15) 16:36	(18) 21:45	(13) 24:45	(16) 30:13	(10) 41:10	(27) 46:40	(21) 49:51	177	17.7	17.7
Wait for empty pallet	--	(37) 3:11	(38) 6:27	(50) 12:07	(41) 17:17	(42) 22:27	(47) 25:32	(357) 36:10	(50) 42:00	(52) 47:32	(40) 50:31	754	75.4	--
Standby and receive empty pallet	100	(10) 3:21	(10) 6:37	(11) 12:18	(09) 17:26	(08) 22:35	(10) 25:42	(26) 36:36	(09) 42:09	(04) 47:36	(12) 50:43	109	10.9	10.9
Miscellaneous Waits		--	--	--	(26) 13:54	--	--	(62) 29:12	(104) 38:20	--	--	192	19.2	--
												3043 (50:43)	304.3	138.3

Standard Working Cycle Time 138.3 Sec.

Balance Allowance 168.7/138.3 = 122%

No. of Men/Gang 4 men

(Total of 8 men working in the Hold under each set of booms, divided into two groups of 4. Each group analyzed separately)

Remarks: Ship's gear drops empty pallet to one group of 4 men, then moves over and picks up loaded pallet from group of 4 men at opposite side of hatch.

Observer:

FIG. 2. Time Study Data Sheet

the total allowances may be reduced to as low as 7.8%. The balance allowance of the slowest or limiting cycle in a typical marine cargo handling operation employing conventional methods will usually be about 45-55%. The use of the balance allowance in synthesizing predicted overall cargo handling speeds is covered in the next section.

(f) *Remarks:* The time study should be carried out in complete frankness and with the full knowledge of the longshoremen that they are being timed. If conditions permit the observer should explain just what data is desired and how it is to be obtained, in as full detail as the longshoremen are interested and their time allows. Frequently much valuable information can be acquired through these discussions, since the longshoremen often know through experience of many important details that might otherwise be overlooked.

Uses of Time Study Information

When time-studies have been taken for all cycles involved in particular cargo handling operations, a comparison of standard working cycle times readily determines the limiting cycle and by how much it is delaying the other cycles. A reasonably exact idea can thus be formed as to the correct area for equipment or method changes and by how much the overall operation will profit. A brief example will illustrate this use of time-study information.

In a typical case, a steamship operator was shipping large annual tonnages of bagged rice. The rice, in 100 lb. bags, was being loaded into the operator's C3 type ships in the conventional manner, by hand loading the rice from the dock floor onto board slings on dock trailers, 18 bags to the board. A tractor then hauled the trailers two at a time to the apron, whereupon the loaded boards were hoisted into the ship's hold, the bags hand-stowed and the empty boards returned to pierside.

From time-studies of all cycles involved it was determined that the standard working cycle times (converted into tons/gang-hr) were as follows:

Cycle	Description	Standard Working Speed (Expressed in Tons/Gang-hr.)
Dock gang	Hand loads bagged rice from dock floor to board slings on trailers (18 bags per trailer)	94.2
Dock tractor	Hauls loaded trailers, 2 at a time to apron, returns with empty trailers	28.5
Ship's gear	Hoists loaded board slings into ship's hold, returns with empty board	38.2
Hold gang	Receives and hand-stows bagged rice, sends back empty board	42.9

From this it can be seen that the limiting cycle is that of the dock tractor, which was found to be traveling an average round trip distance of 760 feet through somewhat congested aisles. The speed of the entire operation was being held down by this one cycle.

At first glance it appeared that an improvement could be

made by doubling-up on the number of dock tractors or by originally locating the rice piles on the dock closer to the ship's loading berth. The first proposal however, involved additional equipment and would lead to greater traffic congestion, while the second proposal was not possible because the incoming rice bags were being hand-stacked directly on the dock floor to shoulder height only, thus using up a great deal of floor space and spreading out the piles. Besides, any improvement in the dock tractor cycle could only speed up the total operation to the level of the ship's gear cycle, which was second slowest. The far higher productivity of the dock gang cycle would still be largely wasted.

The final solution was to separate the dock gang cycle from the others by prepalletizing the rice bags in advance of the ship's loading day. Working with a fork truck the dock gang could then proceed unhindered at its own speed level. The fork truck could tier the palletized loads 5 pallets high, cutting down on the total area requirement and making possible their closer location to the loading berth. On loading day fork trucks could then deliver the palletized loads to the apron without holding up the other cycles.

It was shown that these changes would save the operator approximately 20% in cargo handling costs for the rice loading operation.

Another use of time-study information is in estimating the average productivity of a new idea or design for which no data is available. Frequently in such cases a synthesis can be made of the proposed cycles by combining like elements from existing cycles. In this application it is important that the effects of at least the principle variables on elemental times be known. Such considerations naturally lead to attempts, by assembling a mass of data under controlled conditions, to arrive at standardized time data. The data is represented as varying according to the weight, size or number of packages, the type of equipment in use, the round trip distances or other physical influences as they are deemed significant. Variations in human skill and effort levels are attempted to be leveled through the rating procedure outlined above.

It is still an unresolved question whether such syntheses can be made to predict the actual performance of an individual longshoreman at a specific time, or for that matter, the performance of small groups of longshoremen at a given time. But as a means of predicting average performance of larger groups of longshoremen over longer time periods the synthetic approach is believed valid.

In order to test the usefulness of standard data relating to cargo handling operations the author has since 1948 gathered such data as time permitted, by means of conducting time studies along the waterfront. The studies, when analyzed, revealed that some elements do appear to vary rationally according to physical influences. The somewhat incomplete results to date of these studies are presented by Figures 3, 4 and 5.

A worked-out example will best illustrate how standard

Element	Standard Unit Times
Motion Elements	
1. Hoist loaded balloon sling from Apron, over deck load, drop into lower hold (C3-#3 Hold) Union fall rig.	22.5 Sec.
2. Hoist empty balloon sling out of Lower Hold, over deck load, drop onto Apron (C3-#3 Hold) Union fall rig	28.3 Sec.
Auxiliary Elements	
1. Standby while Hold Gang places sling bars under outgoing pallet	14 Sec.
2. Standby while Hold Gang disengages sling bars from incoming pallet	9 Sec.
3. Standby while Hold Gang unhooks two corners of loaded balloon sling; slowly hoist sling and tumble bags out of sling.	57.4 Sec.
4. Standby while Slingers disengage empty balloon sling, hook onto loaded sling	12.4 Sec.
5. Standby while Slingers disengage drum slings from (3) 42 gal. drums being discharged from ship	22.9 Sec.
6. Standby while Apron Slingers land (3) 1000# bales on pallet, disengage rope slings used to hoist bales out of hold	27.4 Sec.
7. Standby while Apron Slingers disengage sling bars from empty pallet, place under loaded pallet	13.5 Sec.

FIG. 3. Ship's Gear Cycle Standard Elements

Element	Standard Unit Times
A. *Primary Elements:*	
(1) Manhandle 200# crate onto pallet (by tumbling 12 ft)	20.0 sec./crate (4 man gang)
(2) Manhandle 275# bale onto pallet (by rolling 20 ft)	19.3 sec./bale (4 man gang)
(3) Stack 50# carton on pallet (pickup, walk 5', drop in place, return)	2.5 sec./carton (4 man gang)
(4) Stack 100# bag in hold (pickup, walk 4', drop in place, return)	4.3 sec./bag (4 man gang)
(5) Stack 100# bag in hold (pickup, lift 4', drop in place)	7.2 sec./bag (4 man gang)
(6) Stack 50# bag in hold (slide onto shoulder, walk 25' drop in place, return)	3.3 sec./bag (4 man gang)
B. *Auxiliary Elements:*	
(1) Place and secure tie-line around load	30.1 sec/draft (4 man gang)
(2) Grasp sling bars, place under pallet, stand clear while hoisting away	21.1 sec/draft (4 man gang)
(3) Stand clear while empty pallet is set down by ship's gear, disengage sling-bars	12.2 sec/draft (4 man gang)
(4) Stand clear while loaded balloon sling is set down by ship's gear, disengage two corners and assist while ship's gear pulls the balloon out from under load and clear	74.1 sec/draft (4 man gang)

FIG. 4. Hold Gang Standard Elements

data can be used to synthesize the productivity of projected cargo handling operations. In this example on auto and passenger ferry was being designed with provision for 125 tons of general cargo in the lower hold. The designers contemplated loading and discharging this cargo through a small hatch in the auto deck by means of two electric hoists installed in the auto deck overhead. The cargo, which was to be strap-palletized, would be hauled by dock tractor-trailer from the transit shed through the stern loading port onto the auto deck and alongside the hatch. The loads would then be lowered into the hold by the electric hoists, which were to be rigged together similar to union fall gear. In the hold, the palletized loads would be unit-stowed by a small electric fork truck. It was desired to estimate the total time required for this operation to insure that the ferry schedule could be maintained. The prospective owner not having had any previous experience with this particular method, a synthesis was made by combining elemental time data such as that shown in Figures 3, 4 and 5.

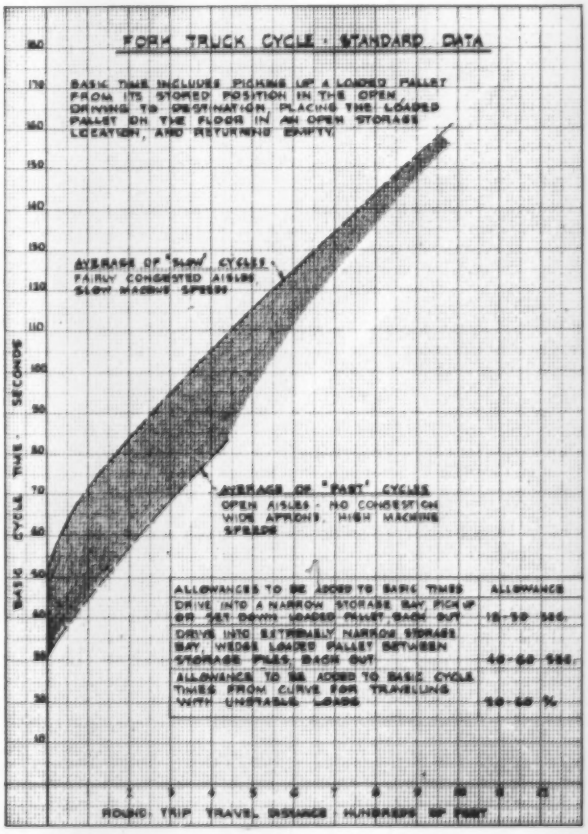
FORK TRUCK CYCLE - STANDARD DATA
BASIC TIME INCLUDES PICKING UP A LOADED PALLET FROM ITS STORED POSITION IN THE OPEN, DRIVING TO DESTINATION, PLACING THE LOADED PALLET ON THE FLOOR IN AN OPEN STORAGE LOCATION, AND RETURNING EMPTY
AVERAGE OF "SLOW" CYCLES - FAIRLY CONGESTED AISLES, SLOW MACHINE SPEEDS
AVERAGE OF "FAST" CYCLES - OPEN AISLES - NO CONGESTION WIDE APPROACH, HIGH MACHINE SPEEDS
ALLOWANCES TO BE ADDED TO BASIC TIMES
ALLOWANCE
DRIVE INTO A NARROW STORAGE BAY, PICK UP OR SET DOWN LOADED PALLET BACK OUT
10-20 SEC.
DRIVE INTO EXTREMELY NARROW STORAGE BAY, WEDGE LOADED PALLET BETWEEN STORAGE PILES, BACK OUT
40-60 SEC.
ALLOWANCE TO BE ADDED TO BASIC CYCLE TIMES FROM CURVE FOR TRAVELLING WITH UNSTABLE LOADS
30-60 %
BASIC CYCLE TIME - SECONDS
ROUND TRIP TRAVEL DISTANCE HUNDREDS OF FEET

Fig. 5. Fork Truck Cycle—Standard Data

Figure 6 shows the synthesis of standard cycle times for both loading and discharging. It is noted that the slowest cycle is the dock tractor, at 240 seconds per round trip.

Handling Palletized Cargo on Auto-Passenger Ferry

Commodity Data: Cargo to consist mainly of canned and bottled goods in cardboard cartons, strap-palletized on 4′ x 4′ pallets. Average draft to be (36) cartons each 55 lbs. or 0.99 short tons per draft.

Estimated Standard Times	Loading	Discharging
(Loading cycle is described—Discharging is reverse)		
Dock Fork Truck Cycle:		
Pickup palletized draft from storage pile tiered 3 high, back out, turn around, set on dock trailer		
Basic time @ round trip distance of 40 ft.	45 Sec.	45 Sec.
Add for narrow storage bays	18 Sec.	25 Sec.
Total estimated working cycle time	63 Sec.	70 Sec.
Dock Tractor Cycle:		
Hitch up to 2 loaded trailers, drive down inclined ramp to ship's auto deck and forward to loading hatch.		
Drop off loaded trailers, hitch to 2 empty trailers, return to shed and drop off empty trailers.		
Basic time @ round trip distance of 820 ft.	240 Sec.	240 Sec.
Allowances (none)	—	—
Total estimated working cycle time	240 Sec.	240 Sec.
Ship's Gear Cycle:		
Standby while auto deck slingers place sling bars under loaded pallet	14 Sec.	9 Sec.
Hoist loaded pallet off trailer, drift over hatch, drop 16 ft. into hold	24 Sec.	20 Sec.
Standby while hold slingers remove slingbars	9 Sec.	14 Sec.
Return to auto deck	20 Sec.	24 Sec.
Total estimated working cycle time	67 Sec.	67 Sec.
Hold Stowage Cycle:		
Pickup loaded draft, turn around, drive to pile, stow draft, turn around, return to hatch square.		
Basic time @ around trip distance of 75 ft.	55 Sec.	55 Sec.
Add for tight stowages	40 Sec.	15 Sec.
Total estimated working cycle time	95 Sec.	70 Sec.

Fig. 6. Estimated Standard Cycle Times

The tractor hauls 2 drafts at a time, however, so the time per draft is 120 seconds. The cycle can further be speeded up by using two dock tractors without measurably increasing the congestion, thus reducing the delivery rate per draft to 60 seconds. The limiting cycle now becomes the Hold Stowage, which is 95 seconds loading and 70 seconds discharging. There being no way of speeding this up without causing serious congestion in the Hold, the standard speed of the entire operation is considered to be equal to that of the Hold Stowage cycle.

The above figures all represent net working times only; to these must be added a balance allowance and an allowance for opening and closing the hatch in order to obtain the gross working time. In view of the working environment and total number of cycles involved, it is considered that a balance allowance of 40% for the Hold Stowage Cycle would be realistic. The standard gross cycle time therefore amounts to:

(a) Loading = 1.4 (95) = 133 seconds = 27.1 cycles/hr.
(b) Discharging = 1.4 (70) = 98 seconds = 36.7 cycles/hr.

At a weight of 0.99 tons/draft this amounts to a productivity of 26.8 tons/hour loading and 36.4 tons/hr discharging. The required time to load 125 tons would be 4.7 hours, while discharging would require 3.4 hours. Including an allowance for opening and closing the hatch and other non-cylical operations the overall loading time is estimated at 5.2 hours and the discharging time at 4.0 hours.

Conclusions

Time study as a means of analyzing labor costs has gained wide acceptance in most industries and has demonstrated its usefulness to management in improving efficiency. It has not as yet been applied in any systematic manner to marine cargo handling operations. With due recognition of the special problems inherent in the marine field, it is believed that properly organized and carried-out-programs of time-study could yield profitable information in this area.

Indeed it is the very number of variables involved in marine cargo handling that makes the potentialities of time-study so great. These many, changing variables make the results of any other form of analysis difficult to interpret accurately or apply to future operations. Time study, by its nature, makes possible the obtainment of cost data together with detailed information as to the physical and human influences governing that data. Such data can be used with full knowledge of its applicability and limitations.

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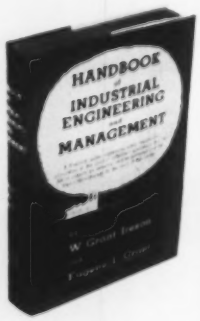

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Economic Manufacturing Lot Size

By Subodh Bhattacharjee

The Johns Hopkins University

Manufacturing processes can be broadly divided into two distinct classifications: continuous or intermittent. Where processes are continuous individual parts move from one operation to another in sequence. No storage of parts is necessary between operations, because each part is transferred to the next operation as soon as it is finished at the present one. Conversely, in the case of intermittent processes, parts are manufactured in batches or lots. One operation on all parts in one batch may have to be finished before the next operation is started. However, it is often possible for two or more operations on the same batch to overlap. We are concerned with only intermittent production in this paper.

The size of the lot produced in one batch has considerable influence on the economic operation of intermittent manufacturing processes. Lot size is often determined arbitrarily. A convenient number such as 500 or 1000 is selected without due regard to the economics of manufacture.

Many manufacturing costs are not affected by lot size but those costs that are affected by the size of the lot can be further classified into two categories: fixed costs and variable costs. Fixed costs are defined as those which are constant for a lot and independent of the number of pieces in the lot. On the other hand, the variable costs are those which vary proportionately with the size of the lot.

The total fixed cost per lot, generally termed "set-up cost", is the sum of the make-ready cost of the machines and the clerical cost associated with the lot. The amount of time required for making the machine ready for production is often considerable in comparison to the actual production time and is independent of the number of pieces in the lot. Also, clerical costs required for issuing and expediting a production order are independent of the size of the lot. For any given amount of fixed costs, the smaller the lot size, the larger the fixed expenses allocated to each piece in the lot. In order to keep fixed expenses per piece as small as possible, it is desirable to have the size of the lot be as large as possible.

On the other hand, the costs of storage, rent, insurance, interest on investment, etc., tend to be constant per unit of product and may be classified as variable "holding" costs. If current production exceeds current demands, inventories increase and these holding costs are increased. The lot size therefore should be as small as possible for the holding cost to be correspondingly small.

There is a lot size for which the total of set-up and holding costs are minimum and this is known as the "Economic Lot Size".

The conventional formula (Camp's formula) (1) for economic lot size is suitable primarily for determining lot size for purchased items. This formula is derived by minimizing the total of the holding costs of purchased parts and the fixed clerical and other costs associated with the processing of a purchase order. It cannot be used to determine economic lot size for manufactured products, especially in those cases where work-in-process inventory is large.

In case of products manufactured in the shop, it is necessary to consider the holding cost of work-in-process during the course of manufacture. As soon as the production of a batch of product is started, capital, representing the cost of material, is tied up. Also the value of materials in process is increased more and more as labor cost is added to it by the performance of successive operations. Considerable time is often necessary from the beginning of the process to the delivery of the finished parts to the stock room. The semi-finished state of the product during this period is called work-in-process. The time from the beginning of the process to the delivery to the stock room is known as "lead time".

During the entire period of lead time, capital representing the average value of work-in-process does not produce any return. Also expenses for storage, insurance, etc., are incurred for holding the product during work-in-process. The holding cost of work-in-process may in certain cases be comparable to and even greatly exceed the holding cost of finished goods. It is, therefore, necessary to consider the holding cost of work-in-process, along with the set-up cost and holding cost of finished goods, to determine the economic lot size.

The conventional formula used for determining economic purchase quantities does not take into consideration the holding cost of the work-in-process inventory. As such, it cannot be correctly employed for determining economic

lot size for products in cases where work-in-process inventory is considerable. The purpose of this paper is to derive a formula for economic lot size which will be applicable when the consideration of work-in-process is necessary. The use and limitations of the formula will be discussed and the results obtained will be compared with those obtained from the simpler formula. Also a criterion will be suggested for deciding when the revised formula should be used.

Derivation of Camp's Formula

The lot size formula derived by Camp takes into account the fixed cost per lot, such as set-up and other clerical costs, and the holding cost of finished goods inventory. The total annual cost is considered and its derivative with respect to the lot size (Q) is equated to zero to obtain the lot size corresponding to the minimum total cost.

Let i = annual rate for the cost of storage and interest on investment in inventory, expressed as a decimal.
c = total cost per piece in dollars excluding set-up cost.
Q = lot size in number of pieces.
Y = total annual demand in number of pieces.
S = cost of one set-up (including clerical and other fixed costs) in dollars.

Then, Average quantity in finished stock $= \frac{Q + 0}{2} = \frac{Q}{2}$,
(assuming a uniform rate of usage)

Average annual storage and other costs (holding cost) $= \frac{Q}{2} \cdot i \cdot c$

Number of set-ups required in one year $= \frac{Y}{Q}$

Annual set-up cost $= \frac{Y}{Q} \cdot S$

Total annual cost = set-up cost + holding cost

$$= \frac{Y}{Q} \cdot S + \frac{Q}{2} \cdot i \cdot c$$

For minimum cost:

$$\frac{d}{dQ}(\text{total cost}) = -\frac{Y}{Q^2} \cdot S + \frac{c \cdot i}{2} = 0$$

$$\text{or, } Q = \sqrt{\frac{2Y \cdot S}{c \cdot i}} \quad \text{(Camp's formula)} \qquad (1)$$

Example:

Let total cost per piece excluding set-up cost, c = \$12.00
Set-up cost per lot, S = \$50.00
Annual rate of storage and other costs, i = 10% = 0.10
Annual demand, Y = 12,000 pcs.
Then, The economic lot size,

$$Q = \sqrt{\frac{2YS}{Ci}}$$

$$= \sqrt{\frac{2 \times 12{,}000 \times \$50}{\$12 \times 0.10}}$$

$$= 1000 \text{ pcs. per lot}$$

Total annual cost = Set-up cost + annual holding for finished goods.

$$= \frac{12{,}000}{1000} \times \$50 + \frac{1000}{2} \times \$12 \times 0.10$$

$$= \$600 + \$600$$

$$= \$1200$$

Comparison of Total Costs for Various Lot Sizes

Economic lot size is defined as that lot size for which total cost is minimum. In the example above the total cost, which varies with lot size, was \$1200 when the economic lot size was 1000 pieces per lot. Any other lot size will result in total cost higher than \$1200. However, we considered only the set-up cost and holding cost for finished goods in arriving at the total cost of \$1200. The holding cost of work-in-process during the period of lead time has not yet been considered. It has been stated before that, when the value of the work-in-process is high and the lead time is considerable, the holding cost of the work-in-process may be considerable. We will compare below total costs, including holding costs for work-in-process inventory, for various lot sizes. It will be of interest to note whether the lot size which corresponds to minimum total cost in this case differs significantly from the economic lot size of 1000 pieces, obtained from Camp's formula. The holding costs for work-in-process for lot sizes 400, 460, 500, 600 and 1000 pieces are calculated and corresponding total costs are given in Table 1.

Holding Costs of Work-in-Process Inventory

Holding costs of work-in-process depend on the value of work-in-process inventory and length of lead time. In the simplest case the lead time for any lot size can be determined by knowing the total time required to make one piece and the number of pieces in the lot.

That is, if:

L = Lead time
t = Total time for making one piece
Q = Quantity in the lot

then, $L = Q \times t$

Total time for making one piece is obtained by adding the time required for all operations. However, as we shall see later, length of lead time depends on actual scheduling of manufacturing operations. Consequently, holding costs of work-in-process also depend on efficiency of scheduling. The lengths of lead time for lot sizes illustrated assume proper scheduling and are given below with other cost data.

The value of work-in-process is obtained by multiplying

unit cost of work-in-process by the number of pieces in the lot. Unit cost of work-in-process is equal to the material cost plus labor cost added to the product during manufacture. Let us consider the following data in connection with the same example for which economic lot size was calculated.

Let lead time for lot sizes of 1000 pcs. = 2.50 months
600 pcs. = 1.50 months
500 pcs. = 1.25 months
460 pcs. = 1.075 months
400 pcs. = 1.00 months

Unit material cost = $6.00 per piece.

Total Cost (excluding setup cost) = $12.00 per piece

Unit labor cost = Total cost (excluding setup cost) − unit material cost
= $12.00 − $6.00 = $6.00

Average cost per piece of work-in-process
= material cost + ½(labor cost)
= 6.00 + ½(6.00)
= $9.00

Annual rate of holding Cost = 10% per year

Annual demand = 12,000 pieces.

$$\text{Holding Costs of Work-in-Process} = \text{average cost per piece} \times \text{number of pieces in the lot} \times \text{manufacturing lead time } \textit{in years} \times \text{annual rate of holding costs} \times \text{number of lots per year} \left(= \frac{\text{annual demand}}{\text{lot size}}\right)$$

Holding costs (annual) of work-in-process for various lot sizes are:

Lot Size	*Annual Holding Costs*
1000 pcs.	$9.00 × 1000 × $\frac{2.5}{12}$ × 0.10 × 12,000/1000 = $2250
600 pcs.	$9.00 × 600 × $\frac{1.5}{12}$ × 0.10 × 12,000/600 = 1350
500 pcs.	$9.00 × 500 × $\frac{1.25}{12}$ × 0.10 × 12,000/500 = 1125
460 pcs.	$9.00 × 460 × $\frac{1.075}{12}$ × 0.10 × 12,000/460 = 1020
400 pcs.	$9.00 × 400 × $\frac{1.00}{12}$ × 0.10 × 12,000/400 = 900

Total Annual Costs

The total annual costs, including holding costs of work-in-process, holding cost of finished goods, and annual set-up costs for lot sizes of 1000, 600, 500, 460, and 400 pieces are shown in Table 1. It will be noticed that the minimum total cost is obtained for a lot size of approximately 460 pieces.

Determination of Economic Lot Size when Work-in-Process is Considered

We have observed before that when only set-up and holding costs of finished goods are considered, economic lot size can be calculated from Camp's formula,

$$Q = \sqrt{\frac{2YS}{ci}}$$

We can now introduce the holding costs of work-in-process inventory in the total annual variable costs and recalculate the formula for economic lot size.

Let m = cost of material at the beginning of process in dollars
c = total material and labor cost of one part, excluding set-up costs, in dollars
i = annual rate for the cost of storage and interest on investment in inventory, expressed as a decimal
Y = annual demand in number of pieces
Q = lot size in number of pieces
t = total time required for all operations for making one part, expressed in years
L = lead time in years;
S = cost of one setup in dollars.

Lead Time

Then, $L = Q \times t$ yrs.

Cost of Work-in-Process for Lot Size Q

The average cost per piece of work-in-process
= material cost + ½ (labor cost)
$= m + \frac{(c - m)}{2}$
$= \frac{m + c}{2}$

The total cost of work-in-process = $\frac{Q \times (m + c)}{2}$

TABLE 1

Lot size	annual set-up cost	+	annual holding cost of finished goods	+	annual holding cost for work-in-process	=	Total annual cost
1000	$\frac{12,000 \times 50}{1000}$		$\frac{1000 \times 12 \times 0.10}{2}$				
	$600	+	$600	+	$2250	=	$3450
600	$\frac{12,000 \times 50}{600}$		$\frac{600 \times 12 \times 0.10}{2}$				
	$1000	+	$360	+	$1350	=	$2710
500	$\frac{12,000 \times 50}{500}$		$\frac{500 \times 12 \times 0.10}{2}$				
	$1200	+	$300	+	$1125	=	$2625
460	$\frac{12,000 \times 50}{460}$		$\frac{460 \times 12 \times 0.10}{2}$				
	$1300	+	$276	+	$1020	=	$2596
400	$\frac{12,000 \times 50}{400}$		$\frac{400 \times 12 \times 0.10}{2}$				
	$1500	+	$240	+	$900	=	$2640

Annual Holding Cost of Work-in-Process

The length of holding time = lead time = L

Holding Cost per unit during the lead time

= Lead time × cost of unit in process

× annual rate of interest and storage cost

$$= L \cdot \frac{m + c}{2} \cdot i$$

Total holding cost per lot

= lot size × holding cost per unit

$$= Q \cdot L \cdot \frac{m + c}{2} \cdot i$$

Annual Holding Cost of Work-in-Process

= holding cost per lot × number of lots per year

$$= Q \cdot L \cdot \frac{m + c}{2} \cdot i \cdot \frac{Y}{Q}$$

$$= Q \cdot Q \cdot t \cdot \frac{m + c}{2} \cdot i \cdot \frac{Y}{Q}, \text{since } L = Q \cdot t$$

$$= Q \cdot \frac{m + c}{2} \cdot Y \cdot t \cdot i$$

Total Annual Cost

Total annual Cost

= annual set-up cost

+ annual holding cost for finished goods

+ annual holding cost for work-in-process

$$= \frac{Y}{Q} \cdot S + \frac{Q}{2} \cdot c \cdot i + Q \cdot \frac{m + c}{2} \cdot Y \cdot t \cdot i$$

For the total to be minimum for a given Q,

$$\frac{d(\text{total cost})}{dQ} = -\frac{Y}{Q^2} \cdot S + \frac{c}{2} \cdot i + \frac{(m + c)}{2} \cdot Y \cdot t \cdot i = 0$$

Therefore,

$$Q^2 = \frac{2YS}{\frac{c \cdot i}{2} + \frac{(m + c)}{2} \cdot Y \cdot t \cdot i}$$

Which reduces to,

$$Q = \sqrt{\frac{Y \cdot S}{\frac{c \cdot i}{2} + \frac{(m + c)}{2} \cdot Y \cdot t \cdot i}} \quad \cdots\cdots \quad (2)$$

Lot Size in Terms of Set-Up and Unit Holding Costs

The above formula can be expressed as,

$$Q = \sqrt{\frac{S}{\frac{1}{2Y} \cdot c \cdot i + \frac{(m + c)}{2} \cdot t \cdot i}}$$

Where,

$\frac{1}{2Y}$ = Average holding time of one unit of finished stock in years

c = Cost per piece

i = annual holding rate

$\frac{m + c}{2}$ = Average cost per piece of work-in-process

t = Holding time per piece of work-in-process in years

But,

Holding time × Cost per unit × annual holding rate = unit holding cost

Therefore,

$$Q = \sqrt{\frac{\text{Set-up cost per lot}}{\text{unit holding cost for finished goods} + \text{unit holding cost for work-in-process}}}$$

Relation of Economic Lot Size to Annual Demand

Holding cost of work-in-process may far exceed that of finished goods. In such cases, the first term in the denominator of the formula (2), the holding cost of finished goods, may be negligible in comparison to the second term, the holding cost of work-in-process. Then the formula for economic lot size will reduce to:

$$Q = \sqrt{\frac{Y \cdot S}{\frac{(m + c)}{2} \cdot Y \cdot t \cdot i}}$$

$$= \sqrt{\frac{S}{\frac{(m + c)}{2} \cdot t \cdot i}} = \sqrt{\frac{\text{set-up cost per lot}}{\text{unit holding cost of work-in-process}}}$$

The lot size in this case is independent of annual demand, and is constant so long as the set-up costs, and the unit holding cost for work-in-process do not change.

When the unit holding cost of work-in-process is negligible in comparison to that of finished goods the formula (2) reduces to Camp's formula: $Q = \sqrt{2YS/ci}$. The lot size then becomes proportional to the square root of the annual demand.

When both holding costs of finished goods and work-in-process are equally important the economic lot size is given by formula (2) and is smaller than either of the two cases discussed above.

The variation of lot size with annual demand for the three cases can be indicated graphically as shown in Figure 1 (2). The curve AB represents the lot size when work-in-process is ignored. The line CD represents the constant lot size when the holding cost of finished goods is not considered. The curve EF represents the lot size when both holding costs of finished goods and work-in-process are considered.

As annual demand increases, the lot size obtained by con-

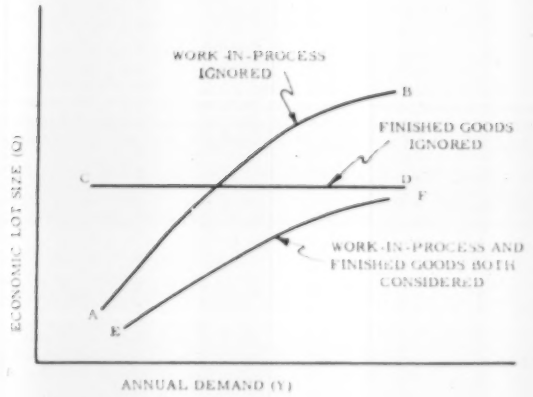

FIG. 1. Variation of Lot Sizes for Three General Cases of Treatment.

sidering both work-in-process and finished goods (EF) varies more and more widely from that obtained by ignoring work-in-process (AB). This suggests that the consideration of holding cost of work-in-process becomes more important for those items which have high annual demand.

Choice of Economic Lot Size Formula

The discussion regarding the nature of variation of lot size with annual demand suggests that, under some conditions, it is only necessary to consider the holding cost of work-in-process in the calculation of economic lot size. Under other conditions, lot size obtained from the consideration of holding cost of finished goods alone is sufficiently accurate for practical purposes. In still other cases, it is necessary to consider the holding costs of both work-in-process and finished goods.

The holding cost of work-in-process is all that is necessary to consider in calculating lot size for a "fast moving" item. On the other hand, the holding cost of finished goods need only be taken into account for calculating lot size for a "slow moving" item. When an item cannot be clearly classified in either category, the holding cost of both work-in-process and finished goods has to be considered.

Two criteria are proposed for classifying an item as "fast moving" or "slow moving". The first requirement is the comparison of holding costs of work-in-process and finished goods. The second criterion is the comparison of holding times for work-in-process inventory and finished goods inventory for a given quantity. An item should be classified as "fast moving" or "slow moving" if and only if both criteria are satisfied. In that case the appropriate simple formula should be used for determining the economic lot size. If both requirements are not satisfied, the item should not be classified in either category and the joint formula, derived in this paper, should be used to determine the economic lot size.

According to the first requirement, an item will be classified as "fast moving" if the unit holding cost of work-in-process is significantly higher than that of finished goods, that is, the numerical value of $\frac{(m+c)}{2} \cdot t \cdot i$ is greater than, that of $\frac{c \cdot i}{2Y}$.

An item will be classified as "slow moving" if the unit holding cost of work-in-process is negligible in comparison to that of finished goods. This implies that the numerical value of $\frac{(m+c)}{2} \cdot t \cdot i$ will be negligible compared to that of $\frac{c \cdot i}{2Y}$.

According to the second criterion, an item is "fast moving" if the length of holding time for a given quantity in the work-in-process stage is longer than the holding time for the same quantity in finished goods inventory. Conversely, an element is "slow moving" if the length of the holding time for a given quantity in work-in-process is negligible in comparison to the holding time for the same quantity in finished goods.

Examples

The classification of items as to "fast moving" and "slow moving", and the effect of considering the holding cost of work-in-process on lot size is illustrated below. The same example which was used to calculate the lot size by Camp's formula is considered. The data are restated as follows:

Example 1

$c = \$12.00$ $\quad L = 2.5/12$ yrs. for 1000 pcs.
$m = \$\ 6.00$ $\quad t = \frac{L}{Q} = \frac{2.5}{12 \times 1000}$ yrs./pc.
$i = \quad 0.10$
$Y = 12{,}000$
$S = \$50.00$

Classification of the Item

Criterion I—Holding Cost Basis:

(A) Unit holding Cost of w. i. p. $= \frac{m+c}{2} \cdot t \cdot i$

$= \frac{\$2.25}{12{,}000} = \$.00019$

(B) Unit holding Cost of finished goods $= \frac{ci}{2Y}$

$= \frac{\$0.60}{12{,}000} = \$.00005$

(A) is nearly 4 times (B); so, the item is "Fast Moving".

Criterion II—Holding time basis:

(C) Holding time for w.i.p. for 1000 pcs. = 2.5 months

(D) Holding time finished goods for 1000 pcs.

$$\text{(selling time)} = \frac{1000}{12{,}000} \times 12 = 1 \text{ month}$$

(C) is greater than (D); so, the item is "Fast Moving".

Lot Size Calculations

(E) Camp's Formula—no w.i.p. considered:

$$Q = \sqrt{\frac{2 \cdot Y \cdot S}{c \cdot i}} = 1000 \text{ pcs.}$$

(F) Revised Formula—w.i.p. and finished goods considered:

$$Q = \sqrt{\frac{Y \cdot S}{\frac{c \cdot i}{2} + \frac{m + c}{2} \cdot Y \cdot t \cdot i}}$$

$$= \sqrt{\frac{600{,}000}{0.60 + 2.25}} = 460 \text{ pcs.}$$

(G) Holding Cost of finished goods neglected:

$$Q = \sqrt{\frac{Y \cdot S}{\frac{m + c}{2} \cdot Y \cdot t \cdot i}}$$

$$= \sqrt{\frac{600{,}000}{2.25}} = 516 \text{ pcs.}$$

The lot size obtained by Camp's formula is very large in comparison to those obtained by the other two formulae. The difference in economic lot size is small whether holding costs for finished goods inventory is considered or not. As calculated in Table 1, total annual cost is minimum for a lot size of nearly 460 pcs. For a "fast moving" item, therefore, the economic lot size should be calculated by the revised formula, which takes into account the holding cost of work-in-process as well as of finished goods inventory. However, sufficiently accurate lot size can be obtained by considering the holding cost of work-in-process inventory alone.

Example 2

Let 360 pieces be the annual demand of the same item considered in Example 1 in place of 12,000 pieces. All the data will be as in Example 1, except the value of Y, which will be changed to $Y = 360$.

Classification of the Item

Criterion 1—Holding Costs:

(A) Unit holding cost of w·i·p $= \dfrac{m + c}{2} \cdot t \cdot i$

$$= \frac{\$0.0675}{360} = \$.00019$$

(B) Unit holding cost of finished goods $= \dfrac{ci}{2Y}$

$$= \frac{\$0.60}{360} = \$.0017$$

(A) is much smaller than (B); so the item is slow moving.

Criterion 2—Holding Time:

(C) Holding time of w.i.p. (30 pcs.) $= Q \cdot t$ (assuming proportionality of lead time)

$$= 30 \times \frac{2.5}{1000} = 0.075 \text{ month. (approx.)}$$

(D) Holding time of finished goods (selling time of 30 pcs.) = 1 month

(C) is negligible compared to (D), so the item is a slow moving item.

Lot Size Calculations

(E) Camp's Formula—no w.i.p. considered:

$$Q = \sqrt{\frac{2Y \cdot S}{c \cdot i}} = \sqrt{\frac{2 \times 360 \times 50}{12 \times 0.10}} = 173 \text{ pcs.}$$

(F) Revised Formula—w.i.p. and finished goods considered:

$$Q = \sqrt{\frac{Y \cdot S}{\frac{c \cdot i}{2} + \frac{(m + c)}{2} \cdot Y \cdot t \cdot i}}$$

$$= \sqrt{\frac{360 \times 50}{0.60 + 0.0675}} = 165 \text{ pcs.}$$

The lot size obtained from the revised formula is very near to that obtained from Camp's formula. In case of a "slow moving" item, therefore, Camp's formula can be used, that is the holding cost for work-in-process can be neglected, for calculating economic lot size.

Example 3

Let the annual demand (Y) of the same item now be 3000 pieces. All other data will be as in Example 1.

Classification of the Item

Criterion 1—Holding Cost.

(A) Unit holding cost of w.i.p. $= \dfrac{m + c}{2} \cdot t \cdot i$

$$= \frac{\$0.562}{3000} = \$0.00019$$

(B) Unit holding cost of finished goods $= \dfrac{c \cdot i}{2 \cdot Y}$

$$= \frac{\$0.60}{3000} = \$0.0002$$

(A) and (B) are of the same order of magnitude. So, classification of the item is doubtful.

Criterion 2—Holding Time.

(C) Holding time of w.i.p. (250 pcs.)

$= Q \cdot t \cdot$ (assuming proportionality of lead time)

$= 250 \times \dfrac{2.5}{1000} = 0.625$ month (approx.)

(D) Holding time of finished goods (250 pieces) = 1 month

(D) is larger than (C). But the difference is not marked enough to definitely classify the item as "slow moving", according to this criterion. The classification of this item is therefore doubtful.

Lot Size Calculations

(E) Camp's Formula—w.i.p. neglected.

$$Q = \sqrt{\frac{2Y \cdot S \cdot}{c \cdot i}} = \sqrt{\frac{2 \times 3000 \times 50}{12 \times 0.10}} = 500 \text{ pcs.}$$

(F) Revised formula—w.i.p. and finished goods both considered:

$$Q = \sqrt{\frac{YS}{\frac{c \cdot i}{2} + \frac{m + e}{2} \cdot Y \cdot t \cdot i}} = \sqrt{\frac{3000 \times 50}{0.60 + 0.562}}$$

$$= \sqrt{\frac{150{,}000}{1.162}} = 360 \text{ pcs.}$$

(G) Holding Cost of finished goods neglected:

$$Q = \sqrt{\frac{YS}{\frac{m + e}{2} \cdot Y \cdot t \cdot i}} = \sqrt{\frac{3000 \times 50}{0.562}} = 516 \text{ pcs.}$$

The lot size obtained by the revised formula (F) is significantly different (approx. 20%) from those obtained by other two formulae. It can be shown that total annual cost is lowest for the lot size of 360 pieces. Therefore, economic lot size for items of doubtful classifications should be calculated by the revised formula.

It can be concluded from above discussions that the consideration of holding cost of work-in-process is important for fast moving items and also for items of doubtful classification. Therefore, the revised lot size formula, which takes into account the work-in-process as well as the finished goods, should be used to calculate economic lot sizes for those items. When the holding cost of work-in-process is negligible in comparison to that of the finished goods, as in the case of slow moving items, Camp's formula may be used. On the other hand the holding cost of finished goods can be neglected when that is very small compared to that of work-in-process, as in the case of fast moving items.

Influence of Scheduling on Lot Size

When the holding cost of work-in-process is considered, the formula for economic lot size is expressed as:

$$Q = \sqrt{\frac{2Y \cdot S}{c \cdot i + \frac{(m + e)}{2} \cdot Y \cdot t \cdot i}}$$

The terms Y, S, m, e, and i are known for any item. The term t has been defined as the total time required to perform all operations on one item.

It was assumed that the next operation is started only after the present one is completed on all parts in the lot. It is obvious that in a manufacturing plant of any size this practice will not be followed unless the nature of the process determines the timing of operations. For considerable time during the process two or more operations may be performed on the same batch simultaneously, thereby reducing the total time of work-in-process per part.

The following simplified example illustrates the situation

Let, Number of operations = 3

Time required per piece per operation = .32 hrs.

Total time per opn. for lot of 1000 pcs. = .32 × 1000 hrs.

$$= \frac{320}{160} = 2 \text{ months (@ 160 hrs. per mo.)}$$

The time required between successive opn. for handling etc. = $\frac{1}{4}$ month

The scheduling of operations is given in Figure 2.

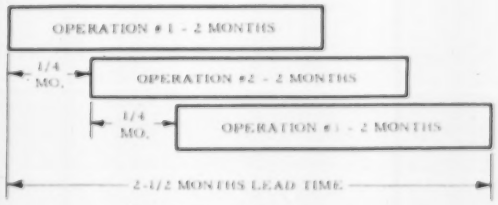

Fig. 2. Production Schedule for a Lot of 1000 Pieces

Lead time, L = 2.5 months

$$t = \frac{L}{Q} = \frac{2.5}{1000} m = \frac{2.5 \times 160}{1000} = 0.40 \text{ hours.}$$

However, if the operations do not overlap, the total time required per piece for all three operations = 0.32 × 3 = 0.96 hrs.

The question may now be asked whether the time per piece obtained from the overlapping schedule for a lot size of 1000 pcs. will remain the same when a lot size of 500 pcs. is processed. Let us draw another simple schedule for a lot size of 500 pcs., assuming that $\frac{1}{4}$ month is still necessary between successive operations for handling, etc. The schedule is given in Figure 3:

$$L = 1.5 \text{ mos.} = 240 \text{ hrs.}$$

$$t = \frac{L}{Q} = \frac{240}{500} = 0.48 \text{ hrs.}$$

The total time per piece now comes out to be 0.48 hrs. in place of 0.40 hrs. as obtained for 1000 pcs.

The unit holding time for work-in-process t, therefore, varies with both the effectiveness of scheduling and the size of the lot processed.

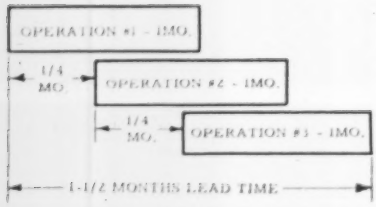

FIG. 3. Production Schedule for a Lot Size of 500 Pieces

When the holding cost of work-in-process is considered, it is necessary to know the holding time per piece t for the work-in-process in order to calculate the lot size.

In the formula:

$$Q = \sqrt{\frac{2Y \cdot S}{c \cdot i + (m + c) \cdot Y \cdot t \cdot i}}$$

t cannot be calculated if the correct lot quantity is not known. It is suggested that as a first approximation the lead time should be determined for an estimated lot size. (The actual lead time may be obtained from previous production records of comparable lots, or from the actual schedule when it is available.) The time per piece calculated from the lead time of the estimated lot size shall be used for the calculation of the economic lot size. If the economic lot size turns out to be much different from the estimated lot size, it can be recalculated using the time per piece, now based on the lot size obtained from the first calculation. Either the first or the second approximation will generally be close enough for practical purposes.

In practice it appears to be satisfactory to assume that the lead time is directly proportional to the lot size within a small range, that is, to assume that if the lead time for 1000 pieces is $2\frac{1}{2}$ months, the lead time for 800 pieces is 2 months. In that case the holding time per piece will be independent of the lot size within that range. The nearer we can estimate the economic lot size, the smaller the initial error will be in calculating t.

Variation of Lot Size with Scheduling and Methods Improvement

From Formula (2) it is observed that lot size is increased when the unit holding time t for work-in-process is reduced. The value of t depends on the length of lead time, and also on the time required for each operation. Whenever there is scope for improvement, the time t can be reduced by increasing the effectiveness of scheduling and improving the methods of production, either of which will result in an increase in economic lot size (2).

Conclusion

Consideration of the holding cost of the work-in-process inventory is often very important in determining the economic lot size for manufactured products. Such consideration is essential in case of "fast moving" items, and less important in case of "slow moving" items. In those cases where the unit holding cost of finished goods is negligible in comparison to that of work-in-process, the lot size becomes independent of the annual demand. On the other hand, when the holding cost of work-in-process is negligible in comparison to that of the finished goods, Camp's formula gives sufficiently accurate results for practical use. The consideration of both work-in-process holding cost and finished goods holding cost is necessary in intermediate cases for obtaining optimum lot size.

Scheduling of production operations also has considerable effect on the economic lot size. The economic lot size can be increased by efficient scheduling and reduction of operation times through methods improvements.

REFERENCES

1. ALFORD, L. P. AND BANGS, J. R., *Production Handbook*; The Ronald Press Company, New York, 1944; pp. 101.
2. RAYMOND, F. E., *Quantity and Economy in Manufacture*; McGraw-Hill Book Company, New York, 1931; pp. 81.
3. RAYMOND, F. E., Economic Production Quantities, *A.S.M.E. Transactions*, vol. 50 MAN, No. 10, pp. 65-80, January-April, 1928.
4. CAMP, W. E., Determining Production Order Quantity; *Management Engineering*, vol. 2, No. 1, pp. 17-18, January, 1922.
5. EIDMANN, F. L., *Economic Control of Engineering and Manufacturing*; McGraw-Hill Book Company Inc., New York, 1931; pp. 245-49.
6. KOEPKE, C. A., *Plant Production Control*; John Wiley & Sons, Inc., New York; Second Edition, 1951, pp. 436-51.

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Journal of Industrial Engineering

READER COMMENTS

The New Industrial Engineering, by D. G. Malcolm, *Journal of Industrial Engineering*, November–December, 1956

Mr. Malcolm's article invites comment on three points:

1. The implication that it is generally possible to optimize simultaneously several variables in the same set of variables.
2. The idea that engineering is moral or even ethical.
3. The idea that "many of our control systems are in essence data processing systems".

On three separate occasions, Mr. Malcolm gives the impression that it is possible to optimize simultaneously several variables in the same set of variables. In his definition of Industrial Engineering (Page 259) and in Box 6, Figure 1 (same page), he states that the objective is "least cost and maximum satisfaction of all parties". Later (Page 261) he refers to "the need to produce the best possible product at least cost". It should be obvious, without reference to formal mathematical concepts, that these objectives cannot be achieved simultaneously. One must decide to produce *either* the best possible product or, the product of least cost. The objective of "least cost and maximum satisfaction of all parties" is also impossible. Not only is it impossible to satisfy everyone in a group of any size by means of a single course of action, but even if it could be done, it is unlikely that the same course of action would be the one involving the least cost.

Engineering is essentially amoral. The principles, techniques and methods of engineering, as well as its products, can be used for evil as well as for good. Ships may be used to bring relief or destruction, communications systems to inform or mislead. Whenever morality is associated with engineering, it is the morality of the engineer not the morality of engineering per se. While morality, or ethics, may have a place in the declared objectives of an engineer or of an engineering society, it has no place in the definition of engineering or of any branch of engineering.

The idea that "many of our control systems are in essence data processing systems" (Page 258) is becoming fairly common. It is quite untrue, nevertheless. A control system is essentially preventive. Production control is designed to prevent loss of time, quality control to prevent loss of product through defective workmanship and cost control to prevent loss of money through inefficient use. Unless the element of preventiveness is present the system is not a control system. The data processing system is, at best, only corrective. It becomes aware of loss from data entered into the system after the loss has occurred. At the very best it can do no more than produce a recommendation for correcting the situation.

In another important respect a data processing system cannot pass for a true control system. The control system consists of four elements; a standard, a variance, a sensor and a controller. The controller, actuated by the sensor when the variance reaches stated limits, takes action to maintain conditions near standard. Thus, the control system must provide means for deriving standards, establishing suitable limits of variability, measuring variances, comparing them with limiting conditions and taking action when action is called for. Data processing systems are much more limited. They can collect and collate data, that is, measure and compare variances, and recommend corrective action, but they cannot, of and by themselves, set standards or determine acceptable limits of variability about those standards. *J. V. McKenna, Associate Professor of Industrial Engineering, Syracuse University.*

Author's Comments

Mr. McKenna's comments are welcomed as constructive and clarifying in the matter of stating the objectives and substance of Industrial Engineering. However, in regard to his point one, it appears that it is *his* misquoting of the passages that have given him the "impression" that I am suggesting a mathematical impossibility.

On page 259, I refer to the "least cost of company money *and worker effort expended*" and again on page 261, the correct quotation should read, "the need to produce the best possible product at the least cost *of money and worker effort*". The italics represent omissions by Mr. McKenna. It is noted that I refer to the *sum* of these two costs and that I do *not* specify the method *nor* the units in which these costs are to be measured.

In general, adequate consideration of the workers' own values, which are not in terms of company money and *do* include consideration of "satisfaction", suggests a "least cost" criterion of greater breadth than Mr. McKenna's implication of only "money costs". It was my hope to convey the thought that it was just such solutions that Industrial Engineers should search for. In this sense I believe it is possible to search for an optimum solution. I suggest that a more thorough reading of the section "Management Decision and the Objectives of the Enterprise" will do much to clear up the unfortunate impression that Mr. McKenna refers to.

In regard to point two, my choice of the word ethical was not precise. It was not my intention to connote morality to the art and science of engineering but rather, by the use of "ethical" as an adjective, to make certain that the objective to be achieved was stated in such a way so as to

include the values of *some* system of ethics. The parenthetical statement following was further elaboration on this point. Despite the fact that my attempt at word economy was misleading, I am not certain, however, that I agree with Mr. McKenna's contention that engineering *is* essentially amoral. First of all, engineering is and has been overwhelmingly devoted to tasks leading to the benefit of the human race. This accounts for its acceptance in our society. Secondly, when the principles of engineering *are* used to evolve instruments of destruction, the use of these instruments is condoned or made "ethical" for this temporal need of the particular society. Lastly, in my opinion when we write concerning "engineering" we are not only thinking of technique but of intentions—in short—we are talking of the *profession* and not of a science.

A definition of the profession of engineering by T. F. Hatch bears on this problem—"the art of organizing and directing men and of controlling forces and materials of nature for the benefit of the human race".[1] Engineering as a profession affects the development of our society and must therefore realize and assume some responsibility for the ethical implications of its efforts.

Mr. McKenna's last point is an excellent discussion on control systems which I concur with. Nevertheless, when control systems are finally designed, installed and are operating, they are also data processing systems—too much so. The electronic computer should make it possible for such systems to better function as control systems.

It was my hope that the article would promote serious discussion concerning the scope and objectives of the Industrial Engineering profession. Mr. McKenna's comments do much to bring out and elaborate several important points. *D. G. Malcolm, Director Of Operations Research: Booz, Allen & Hamilton*

The Standard Process Chart Symbols Need Revision

by Edward L. Page, *Journal of Industrial Engineering*, September-October, 1956.

I hate to disagree with Mr. Page. However, I find most of his arguments foreign to my own experience. First of all, the transportation symbol —› can be drawn quite easily in two basic strokes. A printed arrow ⇨ may be more esthetic, but is no less practical. The area included for symbols is fully as great as for any of the other symbols.

So far as the storage symbol is concerned, a hopper is fully as efficient for storage as a pile. (A hopper may even eliminate some handling in the process.) It must be conceded that a V would make a good hopper. The usual symbol for temporary storage is ▽ . This is easily drawn free hand, and fits the hopper ▽ better than Mr. Page's pile △ .

I am glad to know that Mr. Page has no quarrel with the ○ (Operation) and the □ (Inspection) symbols.

The D for delay is quite convenient in the charting of paper-flow analysis. In these cases there is a definite difference between a "Delay" and "Storage".

So far as confusion of a D with an ○ or a □, I am afraid that such poor free hand drawing could not be tolerated. If draftsmanship is so poor that a D, ○ and □ are confusing, then simple algebra becomes impossible—not to mention the detail required for a good process chart and the analysis of complex systems.

If Mr. Page's suggested revisions are ever put to a vote, I, for one, must reject the proposal—not merely because I am opposed to changes, but because the proposed revision seems to add nothing of value to the system. *Ray Stahl, Industrial Engineer, North American Aviation, Columbus, Ohio.*

Mr. Edward L. Page's article, "The Standard Process Chart Symbols Need Revision", which appeared in the September-October issue of *The Journal of Industrial Engineering*, was read with great interest since the writer served as Secretary of the A.S.M.E. Committee which endeavored to standardize the symbols in 1947. Actually, the major task of this committee involved comprehensive definitions of the scope of the symbols—rather than their configuration. Dr. Ralph Barnes' "Motion and Time Study" illustrates the complete set of symbols proposed by the Gilbreths in 1921, and it will be observed that the accompanying definitions are quite brief. Nevertheless, these original symbols did possess the advantage of variability so that an alternation of one suggested its own meaning. For example, an equilateral triangle was used to indicate the receipt of goods, and the same symbol inverted was used to denote the opposite, or the final disposition of the goods in permanent storage. This characteristic of variability was true throughout the original Gilbreth symbols for the flow of industrial processes, and the late 1930s saw the adoption of similar symbols for office operations which subsequently gained wide acceptance.

It is true that all of these original sets of symbols were confusing in number, and it has been said that this difficulty was recognized by Frank Gilbreth, himself. At any rate, general usage reduced the common symbols to five basic ones which are illustrated separately in Dr. Barnes' text. It was to these that the A.S.M.E. Committee addressed its work of simplification and standardization. If its recommendations did not receive the acceptance expected, a contributing factor would seem to be illustrated in the writer's personal experience.

Paul B. Mulligan & Co. is a consulting organization which had been using process charts as an important tool in defining work-flow prior to the creation of the A.S.M.E. Committee, and prior to the writer's joining it as Research Director. Adoption of the changed symbols would have involved an investment in new templates and reindoctrination of a considerable number of clients. There seemed to be slight advantage in a change, and the original basic Gilbreth symbols continued in use. If another change is

[1] "Human Aspects of Engineering", T. F. Hatch, Mechanical Engineering, May 1949, pp. 406-408.

proposed, it is urged that it be done through channels which would avoid further confusion.

1. Gilbreth's original symbols were presented through the A.S.M.E. in 1921, and their revision came through the same Society in 1947. Any change should be through the same auspices.
2. No change should involve the use of original Gilbreth symbols for a new meaning, since this will lead to misinterpretation. For example, a square standing on its corner was intended in 1921 to represent a Quality Inspection, and it should not be used now to denote a Transportation.
3. Gilbreth's original purpose of variability to indicate related meanings should be preserved in the interests of those who need the use of more than the basic symbols.

The writer agrees heartily with Mr. Page's opening remark that process chart symbols are not of momentous importance, but he is anxious to avoid further difficulties. With this intent, he and his associates are quite willing to assist in any developments in this matter, since the Mulligan Company and its clients use the charts so extensively. *Gideon M. Varga, Research Director, Paul B. Mulligan & Co.*

Interesting the High School Student in the Engineering Profession

A prime requisite for stimulating youthful interest in any branch of learning is the enlightenment of the prospective student as to the scope each field embraces. Since there are fewer men in the engineering field, it follows that less is known about the engineer and his actual duties. There is a desperate need for better information at the high school level—a need which can be filled by AIIE members.

To people living near a technical institute, the engineer is "one of a gang of students"; to those located in an industrial area, he is "a guy who works for the X Company"; and to most business men, he is "the chap who installs the production control system". These varied conceptions are due to a lack of understanding of the functions of a trained technical man. Professional societies do much to publicize his merits, but if the crying need for new material is to be fulfilled, the engineer himself must make known his worth.

Who Is the INDUSTRIAL Engineer?

The industrial engineer is the man who has spent four or more years of intensive study of such subjects as algebra, calculus, geometry, strength of materials, reinforced concrete, machine design, surveying, thermodynamics, hydraulics, power plants, economics, business administration, English, etc. He is the man who sets standards for performance—quality, quantity and cost. He designs jobs and determines the most economical way to do work. He establishes and maintains incentive systems. He analyzes, establishes and evaluates job content. He makes plant location studies, and economic selection of tools, equipment, manufacturing process and assembly methods. He designs systems for controlling production, inventory, quality and cost. He is responsible for the design of equipment layout, service facilities and plant transportation. He plans production flow. He does organization planning and research on operations, and he institutes new methods for industrial safety. These are but a few of the myriad of problems the industrial engineer is called upon to solve. He is ever striving to improve working conditions for man, thereby raising his standard of living.

The failure of the high school student to realize the value of an engineering career is due mainly to the inherent reticence of the engineer, himself, to reveal his activities and their importance to the well-being of the individual; to the betterment of working conditions in industry; and to the progress of the world.

Engineers in other fields tell the public what they do. Let's carry *our* message to the public, and to prospective engineering students. Help your local high schools. *Jack Bull, P. E., Scott & Williams, Inc., Laconia, N. H.*

Encouragement

Recently received your letter confirming my chapter-membership status and dues. I note that the dues have been increased, which I think is quite justified. The impact of your grand exploitation of Industrial Engineering is remarkable. Like our JOURNAL very well. Wish that it were twice as large.

Would like to call to your attention, that when I paid my dues last fall, I sent a check in for two years dues. That amount being $35.00 no doubt that I will be billed only for the amount necessary when that time comes.

Keep up the grand work. *M. Edward Dalen, Industrial Engineer, National Aircraft Corp.*

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RECENT READABLES

AUTOMATION

"Comparing Analog and Digital Computers", by D. B. Breedon, *Machine Design*, page 140, December 13, 1956.

Major differences between analog and digital computers stem from their fundamentally different approach to mathematics. The digital approach permits the use of nothing but elementary arithmetic operations and "yes" or "no" decisions, while the analog approach is one of functional relationships between dependent and independent variables. Any application of computers which varies from this premise does so by making use of additional mathematical formulation.

The author compares analog and digital computers on the basis of capacity, calculation time, set-up time and accuracy.

"Hopper Feeders: Best Bet for Small Plant Automation", by W. G. Patton, *The Iron Age*, August 23, 1956.

Hopper feeders, which can feed machines with parts of many shapes and sizes more quickly, accurately, and safely than human operators, are described by the author as "the poor man's best bet in the hectic race toward automatic manufacturing". This article describes some of the relatively simple, low cost feeders that have enabled some manufacturers to reduce labor costs, increase their degree of quality control, and raise output rates on existing machines by as much as 400 per cent.

FORMS CONTROL

"Organizing Forms Control—Policy Through Program", by Tony Piscatella, *Office Management*, September, 1956.

In spite of high speed electronic data processing equipment, the author says, paperwork in some form is here to stay. This article, which outlines a procedure for setting up a forms control program, emphasizes that management must realize the profit potential in clerical cost reduction and establish forms control as a company policy before any such program can be fully effective.

"All Paperwork Costs are Controllable", by A. C. Sipes, *The Office*, October, 1956.

Pointing out that paperwork costs can amount to half the total sales and administrative costs of a business, the author recommends a comprehensive paperwork control program which would include these elements: (1) reducing the creation of office papers; (2) applying control techniques to handling office papers; (3) using functionally designed filing systems and procedures; (4) providing adequate protection for valuable papers; and (5) instituting storage and disposal schedules. He suggests a number of specific ways in which paperwork procedures can be made more efficient and economical.

GENERAL

"The Importance of Registration in Improving the Status of Engineers", by J. J. Vicker, *Mechanical Engineering*, Page 1103, December, 1956.

The aspirations of the engineering college graduate should be to become a professional engineer and to identify himself in the company of those who are qualified to practice in this profession. To acquire this privilege, he must become a professional person in his thinking and his actions. Thus, professional registration offers to the young engineer a goal of personal development and an opportunity to serve mankind in a more responsible and more privileged manner than that enjoyed by others not so qualified.

"Job Evaluation—A System of Salary Determination", by A. deLeon, Warren Petroleum Corporation, Tulsa, Oklahoma, 1956 ASME Petroleum Mechanical Engineering Conference paper No. 56—PET-18 (available to July 1, 1957).

Inconsistent rate relationships between jobs, resulting from a pay rate not being consistent with job difficulty, is the only major problem job evaluation will solve and unless an adequate salary-administration system is installed in conjunction with the job evaluation study, the cure will be short-lived. A job evaluation system will succeed only if it is installed properly and maintained adequately.

Job analysis is divided into two parts: job description, which is written and gives all operations, methods, conditions, equipment, authority, and other essential facts about a job or position, and job specifications, a list of abilities and qualifications a person must have to perform the job satisfactorily.

The point system of job evaluation is a method by which each job is rated against separate factors and a specific total of points is assigned each job.

"Chart That Job", by L. Resen, *The Oil and Gas Journal*, Page 120, November 5, 1956.

How to do a better job. That's what's behind the work-simplification round-tables being conducted in research affiliates of Standard Oil Co.

The study makes use of a multicolumn flow-process chart which outlines all the steps relating to a particular job. The refiner thereby lays out before him all elements of the job and can study them much as he studies the flow of an operating unit. Wall-size blowups of these process charts were made so round-table participants could follow the discussions.

Use of the technique means ways can be found to short cut, coordinate, or eliminate activities which otherwise are repetitive, time consuming, or actually unnecessary.

MATERIALS HANDLING

"Receiving on the Production Line", by E. L. Greuling, *Modern Materials Handling*, Page 91, December, 1956.

The ideal situation in any high-volume manufacturing operation would be to eliminate receiving and warehousing operations. Materials should arrive at the point of use in the right amounts, at the right time, and so packaged as to be immediately usable.

By directing the development of containers from outside suppliers, Buick Motors is able to cut receiving dock operations to a new low, get the materials to the point of interim storage, and make parts directly available to productive operations.

The basic idea is that all materials shipped to Buick by suppliers, regardless of the nature of their products, shall be packed to permit the use of mechanized material handling devices. This is known as the unit load theory.

"Why Pallet Loaders", by Editors, *Modern Materials Handling*, Page 105, October, 1956.

The area of application for mechanized pallet loaders is expanding rapidly. Recent design developments promise to extend their usefulness greatly. Originally, only plants turning out high volumes with a minimum of product variation could justify the large investment required for a high-speed, fully automatic machine. Now, there are models on the market aimed at the needs of moderate-volume, mixed-lot producers. Such plants have the same basic problems that first became obvious in high-volume industries. This special report goes on to discuss: (1) where pallet loaders fit in today's production; (2) how new designs and developments are attracting more users; and (3) the operating and control techniques for all basic types.

"Air Pillows Cushion Rail Shock", by Editors, *Modern Materials Handling*, Page 103, November, 1956.

Pneumatic dunnage is a potentially safe, efficient and economical method of shoring many commodities shipped by rail box car and applicable to a wide range of dunnage problems. That is what an Army Quartermaster Operations Research Team reported after it conducted a series of tests at Ogden, Utah earlier this year.

The dunnage units are best described as inflatable air bags or envelopes with round corners. They consist of an outer casing of 13 oz. nylon fabric coated with neoprene compound on each side and an inner bladder made of unsupported butyl compound equipped with a large volume diaphragm valve. They are designed to provide a highly elastic and resilient restraining method of preventing cargo displacement and damage.

ORGANIZATION

"Spotting Traffic Jams in Decision Making", by Editors, *Chemical Week*, Page 30, December 1, 1956.

Increasing dissatisfaction with traditional "flow chart" organizational diagrams has spurred a number of chemical process companies in Canada into switching to a new system of charting job titles and functions.

The new method—conceived by Dutch consultant Ernst Hijmans—is called "linear responsibility charting" and is described as a graphic method of analyzing and recording:

1. Corporate, divisional and departmental organization structure.
2. Job content and interjob relationships.
3. Functional operating responsibilities and authority.

There's always been doubt that flow-chart diagrams—originating from military "chain of command" tables of organization—are really suitable for commercial or industrial units. That doubt has been building up as business entities have become larger, more complex, and more dependent on "pooled brainpower" implied in management's concern about keeping channels of communication open and use of "brainstorming" techniques. The author proposes the new method as a solution and describes how it can be used.

"Engineering Organization", by P. Marvin, *Machine Design*, Page 82, November 29, 1956.

Many weaknesses in the engineering program can be traced to organizational defects. Management concern is justified when engineers appear to be an aimless aggregate rather than a well co-ordinated team.

Organization isn't a panacea for every problem in the engineering department, but a sound organization structure will carry the engineering manager over many rough spots that would spell disaster in an otherwise weak organization.

This article presents the four steps essential in the building of an effective engineering organization.

OPERATIONS RESEARCH

"Solving the Transportation Problem", by L. R. Ford, Jr., and D. R. Fulkerson, Page 24, *Management Science*, October, 1956.

A simplified description of a new computing procedure for the Hitchcock-Koopmans transportation problem is given, together with a step by step solution of an illustrative example. The procedure is based on Kuhn's combinatorial algorithm for the assignment problem and a simple "labeling process" for solving maximal flow problems in networks. The proposed computation appears to be considerably more efficient than the specialized form of the simplex method which is in common use.

"Optimal Design and Utilization of Communication Networks", by R. E. Kalaba and M. L. Juncosa, *Management Science*, Page 33, October, 1956.

It is shown that a number of fundamental optimal routing and design problems for communication networks consisting of facilities for transmission, switching, relaying etc., may be treated in a straightforward, computationally feasible manner by linear programming methods. These methods provide a general system approach for resolving the complex interactions among system capacities, users' demands, and economic factors. Various aspects of implementation and generalizations are discussed.

"The Allocation of Aircraft to Routes—An Example of Linear Programming under Uncertain Demand", by A. R. Ferguson and G. B. Dantzig, *Management Science*, Page 45, October, 1956.

The purpose of this paper is to illustrate an application of linear programming to the problem of allocation of aircraft to routes in order to maximize expected profits when there is uncertain customer demand. The approach is intuitive; the theoretical basis of this work is found in an earlier study. The allocations are compared with those obtained under the usual procedure of assuming a fixed demand equal to the expected value. The computational procedure is similar to the fixed demand case, with only slightly more computational effort required.

This paper is intended both for readers interested in routing (and analogous resource allocation) problems and for those interested in studying an example of an application of linear programming under uncertainty.

"A Model for the Optimal Programming of Railway Freight Train Movements", by A. Charnes and M. H. Miller, *Management Science*, Page 74, October, 1956.

The area of railroad scheduling and associated problems offers a potentially fruitful field for research in management science. The mass of data; the need for considering numerous aspects of the problem simultaneously; and the variety of restrictions (arising from the technology, labor agreements and government regulation) make the control of day to day operations a management problem of great complexity. The problems at this level are further compounded by the need for developing, at the same time, methods for planning and evaluating major changes in facilities. Such methods, if they are to be effective, must be capable of tracing out the implications of these changes on the day to day operation and apprising the results in the light of the long run objectives of the railroad. This paper is an account of an attempt to apply certain techniques of management science to some of these scheduling problems as they were found to exist on a large terminal switching railroad.

"Variety in Retailing", by W. J. Baumol and E. A. Ide, *Management Science*, Page 93, October, 1956.

Many marketing problems which promise to be amenable to the techniques of operations research have apparently not been subjected to systematic analysis. This article is a first attempt at an analysis of one such area—the number of

items stocked by a retailer and its relation to his sales, his costs, and his profits.

The analysis of the relations among these variables permits the development of criteria for an optimal variety of items; that is, of expressions which can indicate to the retailer whether an increase or a reduction in the number of commodities, styles and brands which he offers for sale will enhance his profits. The discussion also throws some light on a number of well known retailing phenomena like the growth of suburban shopping centers and supermarkets.

PLANT LAYOUT

"Industrial Plant Layout", by J. B. Harju, *Consulting Engineer*, October, 1956.

Pointing out that sound plant layout means increased production and reduced manufacturing costs, the author examines the many factors involved, from choosing a superior plant site to providing built-in protection from fire hazards. Machine tool layout, materials handling, and other important elements of plant operation are discussed here from the consulting engineer's viewpoint.

"Trimming Costs with Smart Layout", by Ernest Schleusener and Lester Young, *Factory Management and Maintenance*, September, 1956.

Because machine arrangement and materials flow have a significant effect on manufacturing costs, the Mueller Brass Co. has made plant layout an important part of its cost-reduction program. This article describes the improved layout achieved by the company with a 10-step procedure featuring the use of process flow charts, transparent layouts, and models.

WORK MEASUREMENT

"Office Cleaning and Maintenance", by S. Feldman, *The Office*' Page 67, September, 1956.

Cleaning and maintenance operations usually are managed according to the size of an establishment, either by a company's own employees, or a hired firm. Offices in multiple-tenant buildings generally have services such as cleaning floors and emptying rubbish and wastebaskets included in their rent. Some firms, however, engage additional help to take care of waxing and other tasks.

Whether a company has its own cleaning and maintenance crew or hires a contractor to do such work, it is advisable to utilize a check list for regular inspection. This review often uncovers items which need immediate correction and prevents costly repairs.

Included in this article is a list of maintenance time standards and frequencies developed by the General Services Administration, Washington, D.C.

BOOKS

Office Management by C. B. Hicks and Irene Place, Allyn & Bacon, Inc., 70 Fifth Avenue, New York 11, New York, 559 pages, $8.65.

A textbook which emphasizes the management viewpoint. The authors identify the problems and provide guiding principles for planning, organizing and coordinating controls for effective office operation. General management factors are reviewed and applied to office management.

Supervision of Scientific and Engineering Personnel by Lloyd and Gray, Industrial Relations Section, California Institute of Technology, Pasadena, 82 pages, $8.75.

In quick reading outline form, this book checklists every phase of the care and handling of the professional employee. Basic sections cover the characteristics and development of the professional employee, building and maintaining a good technical team, appraisal of performance, the supervisor's role in professional development, policies for salary administration, benefit plans, handling complaints and grievances, unionization of professional employees, communications, organization of a professional work group, what such workers expect of their supervisors.

A Primer to the Automatic Office by Eustis, Dresser, Wyman, and Alden, Automation Management, Inc., Westbord, Massachusetts, 103 pages, $7.50.

Designed as a "first book" for those who want to know what office automation is and how to apply it to their office. Major points covered:

. . . *Thorough analysis of a present system* is needed before investigating machines for automation.

. . . *Where automation is economically justified*, it is quite easy to attain. Because there are now a whole range of standard machines that are capable of handling most jobs.

. . . *Examples of integrated systems* in many types of companies. Most of the examples are from industrial plants.

. . . *All important types* of systems between manual and computer.

Scheduling of Petroleum Refinery Operations, by A. S. Manne, 1956, Harvard University Press, Cambridge, Massachusetts, 185 pages, $5.00.

In this study, intended for petroleum engineers and economists, graphical methods, calculus, linear programming, and several types of nonlinear programming are used in the analysis of representative scheduling problems. The operations discussed are the allocation of crude oils to refineries at different locations; naptha reforming; gasoline blending; and scheduling for a small plant in which cracking, recycling, and blending are integrated. The book also includes a brief review of conventional refinery economic analysis.

Automation, Friend or Foe? by R. H. Macmillan, Cambridge University Press, $1.95.

Automation has already made itself felt technologically and economically; no one, however, has made clear how we are to prepare ourselves either for the crises or the benefits which this "second industrial revolution" is likely to bring about. The author sketches the history of control devices, the gradual evolution of automatic fabricating processes, the problems of control system design, the economics of automation, the operation of computers. A final chapter considers future prospects.

Keeping Pace With Automation, published by American Management Association, 1956, New York 36, New York, 136 pages, $3.75.

A collection of essays and articles by leading manufacturing executives and engineering authorities, selected and edited to form "Special Report No. 7", this volume serves as a practical guide for the company executive. The nature of automation is discussed, with its long-range implications and an assessment of the degree of automaticity achieved in American industry today. The role of management control and of the automatic electronic computer is also covered under "Basic Concepts and Approaches".

The Design and Conduct of Human Engineering Studies, by Alphonse Chapanis, 73 pages, published by San Diego State College Foundation, San Diego 15, California, $2.00.

This booklet presents the results of studies in this relatively new field. Subjects covered include methods of observation, methods for study of accidents and near accidents, experimental methods, psychophysical methods and statistical methods with summarizing, interpreting and experimental data. The book concludes with a discussion of some special problems of experimenting with people, including selection of subjects, methods, and apparatus.

INSTITUTE INTERESTS

SYSTEM SIMULATION SYMPOSIUM

A Symposium on System Simulation is being sponsored by the American Institute of Industrial Engineers, the Institute of Management Sciences, and the Operations Research Society of America, and will be held concurrently with the Eighth National Convention of the AIIE in New York, May 16 and 17, 1957. The Symposium is planned to meet the growing need for an interchange of ideas and experiences in the development of models which simulate business systems. Emphasis will be on the type of simulation which enables the business man and analyst to test ideas and changes in a system and quantitatively determine their effects. Operational-type models which can be used to generate a year's experience in a matter of minutes, along with mathematical types of simulation, will be discussed.

To plan the Symposium, the following committee has been selected: Mr. D. G. Malcolm, Dr. D. V. Hertz, Dr. Tom Caywood, and Mr. J. R. Arwood, with Mr. W. E. Alberts acting as chairman. Mr. Arwood will represent the Host Chapter and the AIIE National Convention Committee.

Attendance at the Symposium will be limited and will be by invitation only. Men who are doing work in the field of System Stimulation and who are interested in the Symposium may contact members of the above committee.

A verbal report on the results of the Symposium will be made at the Friday afternoon session of the Convention. In addition, a printed report will be issued jointly by the sponsoring Societies.

CALENDAR

Commencing this month the Institute Interests section of the Journal will list activities throughout the country of interest to the membership. Listings will be by dates, and will give the name of the activity, the location, and a further source of information for those interested. Considerable advance notice will be necessary to have these activities listed in sufficient time to reach the membership.

Calendar listings for April commence in this issue and the listings will be retained until copy on any particular event is outdated. Mail all listings to N. K. Rogers, Staff Engineer, Systems and Procedures, Waterman Steamship Corporation, 61 St. Joseph Street, Mobile, Alabama. Items sent to the Journal Offices in Atlanta can only be included if received in time to be forwarded to your Institute Interests Editor. Deadline for all listings is the 10th of every odd month in the year. Regularly scheduled chapter meetings will not be listed in the Calendar, as meeting places and dates are generally carried elsewhere in the Journal on an annual basis.

April

25-26, 12th Annual SAM-ASME Management Engineering Conference, Hotel Statler, New York City. Write Public Relations Department, SAM, 74 Fifth Avenue, New York 11, New York.

May

9-10, Fifth Annual Meeting, Operation Research Society of America, Penn Sherwood Hotel, Philadelphia.

16-18, Eighth Annual Conference and Convention, American Institute of Industrial Engineers, Hotel Statler, New York City. Write AIIE National Headquarters, 145 North High Street, Columbus 15, Ohio.

June

12 July 20th, Southern Regional Graduate Summer Session in Statistics, Virginia Polytechnic Institute, Blacksburg, Virginia. Write Boyd Hanhborger, Head, Department of Statistics, V.P.I.

Industrial Engineering Growth

In the November-December, 1956, edition of the *Journal*, Mr. Emerson and Mr. Malcolm used U. S. Census of Population figures in their articles pertaining to the growth of Industrial Engineering. Mr. Emerson would like to correct these figures in the following manner:

"The growth of industrial engineering has been superceded by revisions made by U. S. Census of Population and the latest figures revise downward estimates for both 1940 and 1950, presumably as a result of a reclassification of what constitutes Industrial Engineers. The present totals carried in the latest U. S. Census of Population publications are 12,000 for 1940, 40,000 for 1950. This represents an increase of 28,000 or a 230% increase over the 12,000 in 1940. Don Malcolm's comment that the figures used by the Census are questionable is still true since many individuals perhaps were put into the category of Industrial Engineering as a result of the war.

The latest figure for all engineering increases from 1940 to 1950 was 91%. The increase for Chemical Engineering which was next to Industrial Engineering in fast growth was 160%. Our increase is therefore still impressive.

These revised figures, therefore, do not change the conclusions in either article. Industrial Engineering is still the fastest growing field of engineering.

BIRMINGHAM CHAPTER

The Birmingham Chapter's program for the year 1956-57 is most challenging. It is printed in its entirety as an illustration of the variety and depth that may be achieved through adequate planning for the year's programs.

September 10, 1956

"*Changing Industrial Engineering*", William O. Riley, Chief Industrial Engineer, Atlantic Steel Corporation, P. O. Box 1714, Atlanta, Ga.

October 1, 1956

"*The Use of Industrial Engineering in Government Installations*", Joseph C. Moquin, Chief Industrial Engineer, Army Ballistic Missile Agency, Huntsville, Alabama

November 5, 1956

"*New Uses of Statistics in Work Measurement*", Dr. Robert N. Lehrer, Editor-in-Chief, Journal of Industrial Engineering, Professor of Industrial Engineering, Georgia Institute of Technology, Atlanta, Ga.

December 3, 1956

"*Take a Look at Tomorrow Through Kaiser Aluminum*", B. J. Herman, Chief Industrial Engineer, Kaiser Aluminum and Chemical Corporation, Baton Rouge, Louisiana.

January 7, 1957

"*New Developments in Industrial Engineering*", Howard P. Emerson, President, American Institute of Industrial Engineering,

Head of Industrial Engineering Department, University of Tennessee, Knoxville, Tennessee.

February 4, 1957

"To Be Announced", R. J. Levin, Production Engineer, United Mills Corporation, Mount Gilead, North Carolina.

March 4, 1957

"From Time Study to Industrial Engineering", Jack W. Cammack, Chief Industrial Engineer, Stockham Valves and Fittings Company, Birmingham, Alabama.

April 1, 1957

"How to Measure Fork Truck Performance", Bruno A. Moski, Director of Industrial Engineering, Yale and Towne Manufacturing Company, Philadelphia 15, Pennsylvania.

May 6, 1957

"Federal Mediation", Henry E. Baker, Jr., Commissioner, Federal Mediation and Conciliation Service, Birmingham, Alabama.

Cleveland E. Owen is President and T. H. E. Welch is Program Chairman of this very active chapter.

CENTRAL INDIANA CHAPTER

The Central Indiana Chapter met at The Purdue Union Building in West Lafayette, Indiana, on November 15. The chapter was pleased to have a joint meeting with the members of the Long Range Planning Committee who were attending the 1956 AIIE symposium at Purdue University. We were very fortunate in being able to visit with the following members of the planning committee: W. E. Alberts, Prof. J. Apple, Prof. J. W. Deegan, Prof. H. P. Emerson, G. R. Ewing, R. A. Forberg, F. F. Groseclose, G. H. Gustat, Prof. R. N. Lehrer, D. G. Malcolm, L. T. Ohmart, M. A. Payne, Prof. A. W. Rathe, Dr. A. Schultz, Jr., Prof. W. Steffy, F. J. Titler, G. Wall, A. Western, Prof. E. Laitala, and Dean M. P. O'Brien.

Professor Howard P. Emerson, President of the AIIE, reviewed what had been done and what was being done to advance the national status of the AIIE.

Mr. Ralph Updegraff, Vice President of our Central Region, commented on his position in forwarding information and suggestions received from the chapters in his region to the national office.

Mr. Matthew A. Payne, General Manager of Lubrizol of Canada, Ltd., spoke on the subject of higher objectives of Industrial Engineering. Mr. Payne's talk explored the area of what should be the ultimate aims and objectives of our profession.

Transportation Research Symposium

Under the direction of Professor A. Charnes, Director of Research, Department of Industrial Management and Transportation, and sponsored by The Institute of Management Sciences, the Operations Research Society of America, and the Central Indiana Chapter, American Institute of Industrial Engineers, Inc., Purdue University will hold the first symposium devoted exclusively to the presentation of management research findings in the field of transportation, on February 27-28, 1957, in Lafayette, Indiana.

This Symposium has as its purpose to present the most recent results of management science research in its application to all phases of the transportation industry. It is intended to emphasize and balance in presentation both the point of view of practical operations and the point of view of method or "management science" innovation. It will attempt to stimulate the transfer of ideas developed in one type of transport operations to others. Finally, the Symposium will strive to inaugurate a consortium of fellowship among leaders in transport management and in management science research.

CHARLESTON-HUNTINGTON CHAPTER

Mr. J. L. Hamilton, Executive Vice-President of Island Creek Coal Company, Huntington, West Virginia, spoke to the local Chapter of American Institute of Industrial Engineers in Huntington on November 12. Attending the meeting were 65 members of the local chapter, plant managers and other executives of the several companies represented in the AIIE Chapter.

Mr. Hamilton reviewed his company's use of industrial engineering activities. He stressed the importance of industrial engineering in the coal industry particularly in view of the constantly increasing demand for coal throughout the nation. "Through team work and cooperation, industrial engineering", said Mr. Hamilton, "has found a real important place in our company".

Some of the uses to which industrial engineering has been put at Island Creek, Mr. Hamilton stated, are, one, in creating a sense of cost consciousness among new foremen and other managerial presonnel, two, designing and selecting proper equipment for efficient coal mining, three, developing coal mining and coal preparation methods and, four, projecting costs for future profit determination.

The local chapter of AIIE, which was organized in May 1956, has grown from an initial membership of 35 to its present membership of 60, representing 13 companies in the Charleston-Huntington area. With the present membership, the Charleston-Huntington Chapter is one of the largest chapters of AIIE in the nation.

Also, at this meeting the members and the several plant executives were given copies of a Chapter Membership Booklet. The booklet contains a page for each member on which is printed his picture and information including his employer, job title, address and schooling. The purpose of the booklet is to permit the members to know each other better and thereby foster more ready exchange of ideas and beneficial discussions. The booklet was financed by contributions from companies represented in the chapter.

CHICAGO CHAPTER

On Tuesday, December 11, the Chicago Chapter AIIE sponsored a one-day Work Simplification Clinic. This was their first full day conference, and was highly successful.

The chapter was very fortunate in securing the services of Mr. A. H. Mogensen as the main speaker. Mr. Mogensen is rated as one of the ablest lecturers on the subject of work simplification in the country, and has been active in this field since 1937.

A steak luncheon gave those in attendance ample opportunity to discuss work simplification problems with personnel from many of the outstanding firms in the Middle West.

The luncheon speaker was William G. Caples, Vice President, Human Relations, Inland Steel Company. His subject, "Current Problems in Recruitment in Industrial Relations" was most entertaining.

This one-day clinic demonstrates the active part the Chicago Chapter is taking in providing programs of interest to industrial engineers in that area.

CLEVELAND CHAPTER

The American Institute of Industrial Engineers, Cleveland Chapter, in connection with the Cleveland Technical Society and television station KYW presented a program to high school students interested in a career in Industrial Engineering.

The Program in itself showed the importance of the modern industrial engineer in industry, and also showed a problem that was encountered in the Cleveland Rock Drill Plant, Le Roi Division, Westinghouse Airbrake Company, and how it was solved by modern industrial techniques.

The AIIE Cleveland Chapter conducts conferences to aid students in selecting and preparing themselves for a career in Industrial Engineering, and in addition, gave a $25.00 Savings Bond for the best letter sent in by a high school student on why they would be interested in a career of Industrial Engineering. The winner was William F. Crouse, a student of Shaker Heights High School. This award was highlighted during the TV show.

The Cleveland Chapter AIIE also presented another TV show early in the new year over station KYW, concerning automation and the part played by industrial engineers, and how to interest high school students in Industrial Engineering.

The regular November meeting of the Cleveland chapter was held on November first at Hotel Cleveland. Prof. Ralph Swalm spoke about the contraversial subject "Machine Replacement". Swalm is professor of industrial engineering at Syracuse University. He also serves as an industrial consultant—for both domestic and foreign clients.

As many of the chapter members are or will be actively engaged in plant expansion programs, equipment replacement, or a reappraisal of machinery on hand, the discussion was tremendously informative to the group.

The regular December meeting of the chapter was held on Dec. 6th at Hotel Cleveland. At this session, Robert Kanter, Asst. Director of the UAW—CIO spoke on "Union Attitudes Toward Industrial Engineers". Mr. Kanter is the assistant director of the UAW-CIO Research and Engineering Dept. of Detroit.

Kanter has been engaged in UAW activities for 20 years, having started as a toolmaker in a machine shop. He attended the Detroit Institute of Technology, and is presently working on a master's degree.

He is a member of the A.I.I.E.

The January meeting, held at the Cleveland Hotel, featured a talk by Warren E. Alberts, Industrial Engineer with United Airlines, Chicago, Illinois. His subject was "Industrial Engineering and Operations Research."

Mr. Alberts has made extensive studies of Operations Research, and has spearheaded a very comprehensive project at United Airlines to determine flight schedules, maintenance schedules, and personnel requirements.

DAYTON CHAPTER

Our technical session for January was planned to inform the Industrial Engineer of new developments in fabrication methods. This presentation was given to Mr. K. W. Stalker, Manager of Manufacturing Engineering and Process Development, General Electric Company (Aircraft Gas Turbine Division).

Many new basic approaches to manufacturing processes, useful to many industries, arise from the very difficult fabrication problems inherent in jet engine manufacture. Welding, shaping, machining, and forming high strength metals to close tolerances at reasonable cost are some of the problems involved. Some of the new developments in which Mr. Stalker has been active are chem milling (metal removal by chemical action), spark machining, ceramic tool bits, and very high speed machining. These pioneering efforts and resultings savings were described (with slides) by Mr. Stalker. He also related the significance of cost reduction to winning the economic war, as is now being conducted; this broad perspective should be of high interest to the industrial engineering profession since it emphasizes the important role of the industrial engineer.

Mr. Stalker is a recognized authority in the manufacturing field. He graduated from the University of Colorado with degrees in engineering and social sciences. Later he received a degree in law. His experience has been primarily in the power field both in design and manufacturing. During the past six years Mr. Stalker has been with G.E. in development of new manufacturing processes.

EAST TENNESSEE CHAPTER

The 1956–57 season was opened with a dinner meeting at the University of Tennessee, Student Activities Building. Some sixty members and guests heard Raymond L. Watts, of General Electric Company, Schenectady, N. Y., discuss "Creative Engineering Problem Solving".

Mr. Watts related in detail the functions of the creative engineering training program at General Electric where he is in charge of Course Development for the Creative Engineering Program. After his prepared speech, Mr. Watts answered questions from the audience pertaining to the subject of Creative Engineering.

November 15, 1956, the East Tennessee Chapter toured the Bowaters Paper Company Plant at Calhoun, Tennessee. This is one of the largest of the newsprint manufacturing plants and contains some of the most modern designs of materials handling equipment.

The 4th Annual Regional Conference Southeastern Region will be sponsored by the East Tennessee Chapter on February 15 and 16, 1957.

The East Tennessee Chapter Officers are:

Ronald W. Boling, President
Robert C. Krapf, Vice President (Programs)
M. B. Beverly, Secretary-Treasurer
S. T. Hatcher, Director of Publicity
H. Paul Hassell, Jr., Director of Membership
Hubert O. Criss, Director of Meetings
Howard J. Hicks, Sr., Director of Organization
Wallace D. Kessel and Dr. S. Kyle Reed, Regional Conference Co-Chairmen

FORT WAYNE CHAPTER

The Fort Wayne Chapter of the American Institute of Industrial Engineers has established a $400.00 scholarship in industrial engineering. Eligibility for the scholarship is limited to High School Seniors currently enrolled in any high school located within Allen County, Indiana. The scholarship will be awarded on a competitive basis to a student of outstanding achievement, professional promise and financial need.

The current shortage of engineers in industry has prompted the local organization to provide the scholarship. It is intended to stimulate more interest in industrial engineering among High School Seniors.

Applicants must have the intention of earning a degree in Industrial Engineering or the equivalent at a college approved by The Engineering Council for Professional Development. Three of the most likely applicants will be required to take the Aptitude Test of the College Entrance Examination Board in March, 1957.

The scholarship committee of the Fort Wayne Chapter of the American Institute of Industrial Engineers will select the winner based on: (1) the applicant's high school record, (2) need for financial assistance and (3) the examination scores. Presentation of the award will be made at the Annual Management and Cost Control Conference which the local chapter will sponsor in May, 1957.

The following Fort Wayne Industrial Engineers are serving on the committee: R. E. Awbrey, Chairman, R. Barker, F. H. Bayha, J. H. Buck, W. W. Caple, G. Cripe, J. H. Dimit, W. M. Ferguson, A. Hill, D. W. Karger, L. R. Lenarz, H. Measelle, P. B. O'Neil, E. A. Reinhart, C. A. Wagner, Jr., and M. Zerniek.

INDIANAPOLIS CHAPTER

The Central Indiana and Louisville Chapters have worked jointly to assist in the formation of an Indianapolis Chapter of A.I.I.E.

An Organizational Dinner Meeting was held in Indianapolis, Friday evening, October 26. There were fifty-eight present.

Temporary officers were elected and the necessary organizational committees appointed. Mr. William E. Oliver, Eli Lilly &

Company, Indianapolis, was elected Temporary President. Mr. Oliver has carried the load in the formation of the Indianapolis Chapter.

Short talks were given by members of the Central Indiana and Louisville Chapters on the History, Growth and Objectives of A.I.I.E.

Mr. Don Trenwith, National Headquarters, Business Administrator, extended greetings to those in Indianapolis from the National Organization.

Members present from the Central Indiana Chapter for the dinner were: Mr. H. H. Young, Mr. H. T. Amrine, Mr. C. B. Gambrell, Mr. O. R. Lewis, and Mr. A. B. Rayl.

Those from Louisville were: Mr. J. Rouse, Mr. W. N. Bryant, Mr. C. D. Eldridge, Mr. R. McCormick, Mr. M. Garrett, Mr. R. Robinson, Mr. J. Rigby, Mr. J. Wernert, and Mr. J. Guenthner.

Both Central Indiana and Louisville Chapters extend their best wishes to Indianapolis for a wonderful chapter.

JACKSONVILLE CHAPTER

The Jacksonville Chapter has been conducting a series of round table discussions during the winter months, held at the Mayflower Hotel, at 7:30 P.M., on the second Thursday in each month.

In November, the round table leader was Tinsley W. Rucker, President, Dixon Powdermaker Furniture Company. The topic of the discussion was "How Can the Industrial Engineer Sell His Services to Management?" Student chapter members from the University of Florida attended.

The December meeting had as its topic, "How To Install and Operate a Cost Reduction Program". Mr. J. Fred Mulling, Mine Engineer of Humphrey's Gold Corporation, at Starke, Florida, was the round table leader for the evening.

The first meeting for 1957 was led by M. V. Haas, Management Controls Superintendent, Overhaul and Repair Department of the Naval Air Station. The subject under discussion was "Operations Research".

LOS ANGELES CHAPTER

Activities of the local chapter are increasing at a very favorable rate as indicated by the increasing attendance at this year's dinner meetings. Program Chairman Don Mihelich's "triple threat" agendas comprising technical speakers in the Industrial Engineering field, speakers in other fields—related or otherwise—and an informal technical clinic preceeding each meeting have stimulated the members and encouraged many new guests to awaken to the presence of our group in the Southern California area.

The pre-dinner activities for the November meeting featured the Technical Clinic, which was so well received the previous month. The original clinic featured Robert Edgecumbe's interesting presentation on "Flexible Line Balancing" and Steward Widoff's clarification of "Standard Data vs Time Study in Establishing Standards". The second clinic included Stan Wolfberg's "An Easy Way to Determine Multiple Machine Interference"; Bill Guthries' timely subject "Facility Planning"; and E. Brady's case example of "A Canadian Plant Installation".

Dr. Donald Duncan, Preliminary Engineering Section Chief, Guidance Dept., Autonetics Division, North American Aviation, enlightened the group on the subject of "Inertial Navigation".

Mr. George Brandow, Brandow & Johnston, Structural Engineers; President of the California Legislative Council of Professional Engineers, spoke on the registration of Engineers with particular emphasis to our branch of the profession.

The program was "topped off" with a special film dedicated to all Los Angles Free Way Drivers on the "Hi-Lites of the Mexican Road Races."

December's meeting maintained the fast pace established this year by Program Chairman Don Mihelich featuring a "multiple offense".

Mr. Bill Roberts, President of the Universal Fabricating Company, addressed the group on the subject "Riches Unlimited"; an explanation of the American ways and means of obtaining and maintaining our high standards of living. It was a fine selling job on American Industry and the techniques used to stimulate the individual spirit to promote the best interests of the group. His subject involved the "human relations" aspect of the incentive systems as a supplement to the monetary programs.

Mr. Louis A. Selogie, Associate in Engineering, University of California, Los Angeles, "pointed up" the fundamentals of our profession in a very thought provoking talk on "Engineering in Industrial Engineering". Getting away from the lay interpretation of an Industrial Engineer being synonomous with a Time Study Man, the speaker emphasized the broad characteristics of the field. He used his own varied experiences in the consulting field to illustrate the specialized knowledge and skill in the mathematical, physical, and social sciences required, together with the principles and methods of engineering analysis and design.

Again the "triple featured program" was climaxed by an entertaining film on our continental defenses. The picture "24 Hour Alert" (produced by the popular Mr. Jack (Dragnet) Webb), gave the audience documentary evidence on the latest developments planned for America's protection.

January's pre-dinner clinic featured the top flight array of the following speakers: Messrs. J. F. Fisher and Howard Dickason, both members of the consulting firm of Benjamin Borchardt and Associates, who discussed "A Consultant's Approach to Industrial Engineering" and "Break even Charts Applied to Small Businesses," respectively; and Mr. Walter Herbst, Consolidated Western Steel Co., presented a thought provoking topic, "Stimulation and Maintenance of Management Participation in Industrial Engineering Activities."

The month's feature speaker was Mr. Stan Optner, Member of the Technical Staff of Ramo-Wooldridge Corp., discussing the "Ingredients of Successful Machine Loading."

Participating in a joint venture with other technical groups—S.A.M., A.S.M.E., A.S.Q.C., M.T.M., and Systems and Procedures Association—the local chapter sponsored a "Ladies Night" meeting featuring the eminent Dr. Lillian Gilbreth, speaking on "Management in Industry and the Home." The general theme of the meeting and the co-sponsorship arrangement proved to be very successful in promoting a very large attendance and giving the various groups an opportunity of exchanging mutual ideas; not to mention the opportunity for the Ladies to find out "first hand" what their men are supposed to be doing both at Home and at the Plant.

Another highlight of the month's activities was the presentation of the Special Fellow medal to Dr. Ralph Barnes, presented directing activities at the University of California at Los Angeles, for his outstanding contributions in the Industrial Engineering field. Not the least of Dr. Barnes' contributions in the field were his particular efforts in initiating the foundation for the development of the Los Angeles Chapter, which has grown in a few short years to its present complement numbering 200 members.

The month of March saw a continuation of the joint sponsorship idea, this time with the Methods Time Measurement group. The evening featured a panel discussion of the M.T.M. techniques, expounding both the theory and the actual application to local industrial situations.

The evening's pre-dinner clinic featured Don Knapp, Servo-Mechanisms Inc., speaking on "People and Plants and How to Get Them Together;" Will Whitson, Management Consultant, discussing "Special Phases of Management Consulting;" and Mr. Robinson, who enlightened the group on the subject "Industrial Engineering in Chicken Farming."

The long range planning for the 1958 National Convention to be held in Los Angeles has evolved a special Committee headed up by Mr. Howard Dickason. The committee has passed the outline

stage and is currently delegating the various assignments to the chapter members to insure the participation of the group and the success of the forthcoming event.

LOUISVILLE CHAPTER

The Louisville Chapter continues to present programs of the highest quality in their monthly meetings.

In October, Mr. Thomas E. Bartlett, Assistant Professor of Industrial Engineering at Purdue University, spoke knowingly on the application of linear programming.

In November, Dr. Irwin P. Lazarus, Director, Ordnance Management Engineering Training Program, U. S. Army, discussed development with management controls. Dr. Lazarus stressed the three step method of establishing proper control systems in large organizations: Plan, Follow up, Corrective Action. Dr. Lazarus showed many slides of various control graphs and devices to augment this control system.

In addition, two other distinguished guests spoke during the evening. Art Briese graciously consented to sit in on the meeting and relate a few of his anecdotes. The other guest was Ralph W. Updegraff, Vice President of the Central Region.

The December meeting featured a program on quality control presented by Mr. Edward M. Schrock, Quality Control Engineer with American Standard Company. Mr. Schrock helped found the American Society of Quality Control in 1946, and has worked in this field since prior to World War II. His talk was received enthusiastically by the large number of members present.

MEMPHIS CHAPTER

Our meeting November 21, 1956, at 8:00 P.M., was held at Memphis AF Depot, 3300 Jackson Avenue. After a short business meeting, Mr. Harold Runft and Lt. Richard Deininger of the Logistic Data Processing Office of Memphis AF Depot presented a program on *Electronic Data Processing with the IBM 705 Digital Computer.*

Mr. Runft is Deputy Chief of the Logistical Data Processing Office, and Lt. Dininger is assigned to the Operations Research Group of that office. This was a good program as both these speakers are top-notch men in their field.

In December, the Memphis Chapter was fortunate enough to have as a speaker Mr. E. L. Slagle, past President of the American Institute of Industrial Engineers. Mr. Slagle, who is associated with the U. S. Steel Corporation, spoke to the members on the part they could play in the "Organization and Future of the American Institute of Industrial Engineers".

In January, Lt. Robert I. Millard, USAF, who was formerly with the Industrial Engineering Division, Eastman Kodak Company, served as a commentator on the subject "Standard Time Accounting". Lt. Millard is assistant engineer at the Mallory AF Depot and was well qualified to lead the discussion on the application of time study data to the formulation of a standard cost program.

The Organization Committee has completed a revision of the chapter constitution for vote by full membership and has brought the organization into agreement with some of the recommendations that had been made from time to time by the national headquarters. The Memphis chapter is to be congratulated on taking an active step toward making their organization a streamlined and workable group.

MIDDLE TENNESSEE CHAPTER

One of the most recent additions to the growing family of Senior Chapters is number 64, the Middle Tennessee Chapter of Tullahoma, Tennessee.

The Middle Tennessee Chapter had its initial meeting in Tullahoma, "The Queen City of the Highland Rim", May 8, 1956, through the organizational efforts of Robert L. Koger and Wendell B. Graddy of Tullahoma. The group got off to a stimulating start by successful efforts of the organizers to secure the services of Professor Howard Emerson, Head of the Department of Industrial Engineering, University of Tennessee and National President of the AIIE, as guest speaker.

Officers elected pro tempore at this meeting were:

President—Wendell B. Graddy, ARO, Inc.

Vice-President—William E. Prather, General Shoe Corporation

Secretary—W. T. Gentry, U. S. Rubber Company

Treasurer—Robert L. Koger, ARO, Inc.

Subsequent summer and fall meetings of the budding organization were held at the AEDC Officers' Open Mess and were highlighted by guest speakers who are prominent figures in Industrial Engineering and related fields of endeavor. Richard Bruckart, Professor of Engineering at Texas A and M College, was the speaker for the June meeting. Professor Bruckart's topic was "Industrial Engineering in the Holy Land." Guest speaker for the July session was Professor John A. Henry, of the Mechanical Engineering Department, University of Illinois, who spoke on "Quality Control as a Management Tool." In August, the meeting was for members and their wives. Professor George Thuering, of Pennsylvania State College, gave an interesting talk on "Work Sampling," that entertained both the members and their wives. The next meeting was in October and the speaker for the meeting was Dr. J. F. Bailey of the University of Tennessee. Dr. Bailey discussed "The University of Tennessee Graduate Degree Program at the Arnold Engineering Development Center."

The Middle Tennessee Chapter received its charter from the national headquarters in Columbus, Ohio in October and immediately proceeded to nominate and elect officers.

The December meeting was in the form of an open meeting for membership participation in discussion on policy, projects and agenda for the next year. The membership voted to have meetings at various plants and factories in Middle Tennessee and to arrange for tours and discussions with plant personnel. Projects discussed included engineering career guidance programs for high school seniors, sponsorship of a technical film distribution center, and programs where the "creative thinking" concept can be employed.

Officers and Directors Middle Tennessee Chapter of the AIIE.* *Sitting Left to Right:* Milmer Babyer, Treasurer; Wendell Graddy, President; Edward Prather, Vice President *Standing Left to Right:* Miles Maynard, Constitution; Robert Koger, Membership and Qualifications; Ernest Teasley, Programs; Thomas Bigger, Publicity

*Harry Ginn, Secretary, was absent when photograph was taken.

PHILADELPHIA CHAPTER

The Philadelphia Chapter was honored to have Phil Carroll, Northeastern Regional Director of the AIIE, as its November speaker. Mr. Carroll's topic was "How to Chart Timestudy Data". Mr. Carroll recommended the use of standard data for setting time study standards. He explained the use of various techniques for charting timestudy data. Mr. Carroll stated that the goal of every good incentive program should be 100% company-wide coverage. Incentives should be applied to indirect and clerical operations as well as to all direct work.

The measurement of clerical and indirect work are areas which have been frequently neglected in the past and, therefore, represent a real challenge to the industrial engineer. Mr. Carroll's approach to this problem is to present standards by means of standard data. He stressed the need for consistency in setting standards. The benefits of a good incentive program are greater productivity, lower unit overhead cost, better planning and control, and increased earnings for the worker. Mr. Carroll recommended the use of a one for one incentive plan for production above standard.

The speakers at the December meeting were Mr. Michael Damroth, Senior Industrial Engineer, Merck Sharp & Dohme, division of Merck & Co., Inc., and Mr. James R. Keogh, Jr., Manufacturer's Representative. Their subject was "Installation of Automatic Materials Handling Systems". Mr. Damroth is the incumbent President of the Philadelphia Chapter. Mr. Keogh is a past President of the Chapter.

Mr. Damroth discussed the thinking that the industrial engineer must use in planning and designing automatic materials handling systems. He stressed the need for creative imagination in approaching materials handling problems. The industrial engineer should approach each problem with an open mind. He should never let his thinking be restricted by a pre-established product, know how, or facility.

Mr. Keogh discussed various case histories illustrating the thinking and problems involved in installing automatic materials handling systems.

PITTSBURGH CHAPTER

The first meeting of the 1956-57 series for the Pittsburgh Chapter was held on November 7 at the Westinghouse Educational Center. The principal speaker was Dr. Lillian M. Gilbreth, who delivered a very inspiring message on the "Human Side of Automation". Mr. M. A. Payne, former national president of AIIE, outlined the advantages of a professional industrial engineering society and cited the phenomenal growth of the AIIE. This meeting was attended by a capacity turn-out of over 200 persons.

Mr. R. O. Ferguson, Vice President of Methods Engineering Council, was the principal speaker at the second meeting on December 5. His discussion, "The New Decision Making Tools of Management", reviewed in a practical manner such Operations Research topics as Linear Programming, Queueing Theory, and Game Theory. Mr. Ferguson is the author of a forthcoming book *Linear Programming Fundamentals and Applications* to be published by McGraw-Hill.

W. R. Turkes, Associate Dean of the Schools of Engineering and Mines at the University of Pittsburgh, and A. G. Holzman, Associate Professor of the Industrial Engineering Department of the University of Pittsburgh, have served as co-chairmen for the November and December meetings and have directed the organization of an Industrial Advisory Council to stimulate the interest of Pittsburgh industry in the local chapter of AIIE.

SAN DIEGO CHAPTER

We have been waging an aggressive membership drive lately with the net result that we doubled our active membership during the three summer months. The applications are continuing to come in steadily and we fully expect to triple our previous high by the end of December. Part of this success has been due to a hard driving membership campaign and also to a very much improved program setup.

As an illustration of the latter at our last dinner meeting we had one hundred and thirty attendees. Our program consisted of a panel type discussion on the subject 'What Top Management Expects From an Industrial Engineering Department'. The panel members were: Moderator, Tod Carter, Industrial Engineer, Solar; Speakers, Capt. R. H. Wallace, Prod. Officer, U. S. Naval Repair Facility; L. M. Limbach, Vice Pres., Manufacturing, Ryan; W. G. Dollmeyer, Vice Pres., Operations, Solar; B. F. Raynes, Vice Pres., Manufacturing, Rohr.

Since last April we have never had less than 100 meeting attendees and the programs have been extremely well planned and interesting.

Plans are going ahead steadily for an outstanding Western Regional AIIE convention next spring. It will be held at the Coronado Hotel in Coronado (San Diego), California. From all indications it promises to be one of the finest engineering type conventions that has ever been held on the West Coast. James Nordahl, Western Regional Vice President, met with our Board of Governors recently and expressed approval of the preliminary planning that has already been completed.

The San Diego chapter meets regularly on the second Tuesday of each month for a dinner meeting at the exclusive Cuyamaca Club. Any and all industrial engineers who may be in the area are cordially invited to attend.

SAN FRANCISCO-OAKLAND CHAPTER

The above picture shows S. F. Oakland Chapter members, Frank Taylor and Roy Kahn presenting a work simplification program to a group of Oakland High School "Junior Achievers". This program was developed especially for junior achievement companies as one of the Chapter's educational projects. Its purpose is to demonstrate to the achievers how their enterprises can be made more successful by improving methods and eliminating waste of effort, time and materials. Last fall, a team of 12 speakers toured the Bay area and presented the program to a large number of the junior companies for the first time. Results to date indicate that it has been very successful.

On Sept. 20th, James D. Nordahl, Chapter member and Western Regional Vice President, addressed the first meeting of the University of California Student Chapter at Alumni House in Berkeley. Jim presented some very interesting facts concerning I.E. opportunities on the west coast as well as a very frank discussion concerning what the future engineers could expect to be doing in the early days of their professional careers. This Chapter has always been interested in the activities of the local student chapter and one of the events looked forward to each year is the

annual joint meeting. The meeting this year was held at the beautiful Claremont Hotel in the Berkeley Hills and featured a most interesting talk by Consulting Engineer, Kenneth C. Carver, on unusual applications of I.E. techniques. The meeting was followed by a social get together allowing students and practicing engineers to meet and talk.

Another Chapter member, Prof. E. C. Keachie, of the University of California, appeared before the television cameras of Local Educational Channel 9 on the night of Dec. 3rd. In an interview type program, he brought out many interesting facts concerning the field of industrial engineering and several examples of practical I.E. application were shown. Prof. Keachie also urged young people to consider the field of industrial engineering as a career. At conclusion of the program, viewers were asked to write to the station for a free copy of the brochure "Opportunities Unlimited in Industrial Engineering".

SAVANNAH CHAPTER

The September meeting of the Savannah Chapter was a plant tour of the Derst Baking Company in Savannah. The group was shown the various operations of bread and cake making, and a short business meeting was held afterwards.

Mr. J. M. MacBrayne, Regional Vice President and member of the Savannah Chapter Board of Directors, gave a talk to the Winston Salem Chapter of AIIE at Winston Salem, N. C., in September. His subject concerned the shortage of teachers in high schools trained to teach science and engineering courses. Mr. MacBrayne stressed that the industrial engineer should meet professional responsibilities by volunteering to teach science classes in high schools where there are shortages, and to get into community activities in their area. He pointed out that industrial engineers are trained to analyze situations which could be of great help in community projects.

The October meeting of the Savannah Chapter was a panel discussion on the shortage of trained science teachers in Savannah schools. Members of the panel were:

J. M. MacBrayne, Vice President for Southeast Region AIIE
W. A. Early, Superintendent of Schools and past N. E. A. President
S. T. Nutting, Savannah Chapter AIIE President
R. J. Cummings, Southeast Regional Director for AIIE
J. M. Parr, President of Joint Council of Engineering Societies in Savannah

Guests included members of the Joint Council, representatives of Active Citizens for Education, the Armstrong College, and other interested groups. The meeting was essentially an ideas meeting in which the whole group developed the discussion started by the panel. A number of ideas were suggested during the meeting; such as, part time teaching, sponsorship of scholarships, and orientation of secondary school children to the scientific professions. A motion was made to have the subject brought up at a meeting of the Joint Engineering Council of Savannah.

The November meeting was held in conjunction with the Joint Engineering Council of Savannah on November 14 at the Hotel Manger in Savannah. This meeting was sponsored by the American Society of Civil Engineers who obtained for a speaker, Brig. Gen. George Morris, who is Chief Engineer of the Vicksburg, Miss., area of the Corps of Engineers. His subject was "Civil Works in a Changing Economy."

The Savannah Chapter of AIIE sponsored a Joint Council meeting last year. We were privileged at that time to have as a speaker, Col. E. F. Groseclose, member of the Editorial Board of the Journal of Industrial Engineering and head of the Industrial Engineering Department at Georgia Tech. His subject was "Automation".

ST. LOUIS CHAPTER

A December meeting of the St. Louis Chapter was held December 12, 1956, at Ruggeri's. Following a dinner, Mr. Robert Kanter, Assistant Director of the United Auto Workers' Research and Engineering Department, spoke on some labor-management problems and promises of tomorrow.

Mr. Kanter's appearance on the program was a return engagement. He is an outstanding speaker in the field of labor relations, having spent the last 16 years in engineering work with the International Union, U.A.W.

Mr. E. H. Walker, Industrial Engineer in the Operations Division of Granite City Steel Company, was Chairman for this program.

At the general meeting Mr. Dickey Dyer, a public relations man for Welling & Woodard, spoke on "Compatibility – a Requirement for successful mergers as well as successful marriages".

The unusual title for Mr. Dyer's talk evolved from his long experience as management councellor on such wide range subjects as: mergers, expansion and diversification of products and markets. The talk gave the audience a wider perspective on the Industrial Engineers' place in business and the correlation of their function with top management thinking.

W. L. Penniman of International Shoe Co., St. Louis, acted as chairman for this meeting.

TULSA CHAPTER

The Tulsa Chapter of AIIE had at its December meeting Mr. C. E. Thompson, P.E., Director of Operations Research at the Oklahoma Institute of Technology, Oklahoma A. and M. College. The program subject was, "Applications and Principles of Operations Research." Mr. Thompson began his subject with explanations of linear programming and demonstrated case examples where problems with only two dimensions could be solved. He progressed to the use of O. R. in the solving of multi-dimensional complex problems. Also discussed was why industrial engineers are particularly well suited for this field of research, and what they need to equip themselves for this expanding trend in business. Mr. Thompson was selected to direct the operations research activities at O.I.T. after having spent several years in research and development studies. He holds a Masters Degree in Chemical Engineering and is active in consulting work.

At its January meeting the Tulsa Chapter had as its guest speaker Mr. D. F. O'Donoghue, Assistant Vice President, Overhaul, American Airlines Overhaul and Supply Depot. His subject was, "Administration of Industrial Engineering." Mr. O'Donoghue's experience with Industrial Engineers and working in industrial engineering makes him well qualified to discuss administrative aspects of the field. Before joining American Airlines as an Assistant Vice President, Mr. O'Donoghue was employed by the Kaiser Metal Producing Company. While at Kaiser he was Works Manager and Standards Officer.

WINSTON-SALEM CHAPTER

One of the most successful meetings of our organization's history was held on November 27, 1956, when 174 members and guests representing 16 varied industries attended a dinner meeting to hear Miss Bonnie B. Small, Department Chief of Statistical Process Quality Control, Western Electric Company, Allentown, Pennsylvania Plant. She spoke on "Quality Control for the Engineer," which created considerable interest as indicated by the questions asked the speaker concerning specific applications of quality control processes presented.

Our chapter is continuing to strive for a more diversified program of speakers and activities to increase our membership from approximately 70 members and gain a greater representation of the many industries located in this area.

The American Institute of Industrial Engineers

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on

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THURSDAY—May 16, 1957

MORNING:

Keynote Address: The Industrial Engineer of Tomorrow
Peter F. Drucker
Management Consultant and Author

Topic: Organization—A Management Tool
M. R. Lohmann
Dean
Oklahoma Institute of Technology of the Oklahoma Agricultural and Mechanical College

Topic: How to Recognize the Need for an Industrial Engineering Program
H. B. Maynard
President
Methods Engineering Council

Topic: A Progress Report on Operations Research
O. A. Hoffman
Manager, Operations Research Group
American Machine & Foundry Co.

Topic: Profit Planning and Responsibility Reports
J. C. Freeman
Controller
Dresser Industries, Inc.

Topic: How to Set Up an Industrial Engineering Department

E. E. Querbach	K. O. W. Sandberg
Senior Industrial Engineer	Plant Manager
American Cyanamid Co.	General Electric Co.

Topic: Centralized Data Processing in a Decentralized Company
L. Guest
Controller
Sylvania Electric Products Inc.

LUNCHEON: Luncheon Talk
Ropes of Gold
Kenneth McFarland
Sponsored by
General Motors Corp.

AFTERNOON:

Topic: The Industrial Engineer as an Aide to Top Management
H. E. Nourse
Vice-President
United Airlines

Topic: New Methods & Approaches in Work Measurement
L. Brouha, M.D.
Physiologist
E. I. du Pont de Nemours & Co.

Topic: A Case Study in Industrial Engineering

C. Day	H. Asheroft
Vice President—Manufacturing	Works Manager
Bausch and Lomb Optical Co.	Bausch and Lomb Optical Co.

Topic: Applying Statistics to Industrial Engineering
A. R. Crawford
Operations Research Section
Esso Research and Engineering Co.

BANQUET: The Earth Satellite Project
N. E. Felt, Jr.
Operations Manager
Glenn L. Martin Co.

FRIDAY—May 17, 1957

MORNING:

Topic: Incentives—Pro & Con

Pro: Phil Carroll	Con: Don A. Rudkin
Professional Engineer	Manager of Industrial Engineering
	Merck & Co., Inc.

Topic: Union Influence in Management Decisions
H. S. Hall
Partner
Hall & Lange

Topic: New Techniques in Production Scheduling & Planning
H. Knippenberg
Product Manager
Compression Fittings
Dresser Industries, Inc.

Topic:	Are We Going Overboard with Cost Figures? I. W. Keller Controller Armstrong Cork Co.
Topic:	Inventory Control by Operations Research D. G. Malcolm Director of Operations Research Booz, Allen & Hamilton
Topic:	Human Relations Research as it Affects Industrial Engineering C. Argyris Associate Professor Department of Industrial Administration Yale University
Topic:	How to Make a Computer Feasibility Study P. A. Toll Data Processing Systems Manager Sperry Gyroscope Co.
LUNCHEON:	Luncheon Talk American Know-Why Dwayne Orton Editor, THINK, and Educational Consultant International Business Machines Corporation President, Council for International Progress in Management

AFTERNOON:	
Topic:	Report on the Joint AIIE-ORSA-TIMS Systems Simulation Symposium Warren Alberts Director of Industrial Engineering United Airlines
Topic:	Progress Report on Work Simplification H. F. Goodwin Assistant Professor, Industrial Management Massachusetts Institute of Technology
Topic:	The Industrial Engineer and Quality Control J. M. Juran Consulting Management Engineer
Topic:	A New Approach to Records Management A. Barcan Executive Director Records Management Institute
Topic:	Closed Circuit T. V. Reviews the Industrial Engineering Mainstream Moderator: Chet Huntley News Analyst National Broadcasting Co. Intimate, behind-the-scenes interviews . . . made possible by the T. V. camera . . . on new applications, new research and new approaches in industrial engineering. Operators and camera supplied through the courtesy of the General Precision Laboratory, Inc.

The Conference—Thursday and Friday—is open to non-members as well as members. The Convention meeting on Saturday is open only to members.

For a detailed announcement or registration write to: AIIE, P.O. Box 8, Substation 135, New York 53, New York.

SCHEDULE OF FEES

	Member	Non Member
Full Conference This includes all sessions on Thursday & Friday and two luncheons and one banquet. The Convention business sessions on Saturday are free. The Convention luncheon on Saturday is not included.	$37.50	$48.50
Thursday Only All Thursday sessions and one luncheon	$18.50	$24.00
Thursday Sessions Only	$14.00	$18.00
Thursday Luncheon Only	$7.00	$9.00
Friday Only All Friday sessions and one luncheon	$18.50	$24.00
Friday Sessions Only	$14.00	$18.00
Friday Luncheon Only	$7.00	$9.00
Saturday Convention Luncheon (open only to members)	$5.50	—
Saturday Convention (for members only)	free	
Banquet Only (on Thursday)	$10.00	$13.00
Proceedings Only	$4.00	$5.00
Undergraduate Students, High School Teachers & Vocational Guidance Counsellors All Thursday and Friday Sessions. Luncheons and Banquet are not included.	$3.50	$3.50
Ladies Program For the wives of full registrants. This includes the Thursday banquet, a gift and a program of activities during the Conference	$10.00	$10.00

NOTES:

1. Transactions are included free of charge with full advance registrations received before May 1, 1957.
2. There will be speakers at all luncheons and the banquet.
3. Unfortunately, luncheon and banquet seatings can be guaranteed only if advanced registrations are made.

CONFERENCE EXHIBITS

OLIVETTI CORPORATION OF AMERICA

580 Fifth Avenue, New York 36, New York

The new Olivetti Tetractys, is the most advanced of all desk type printing calculators. Its combination of high speed, short cut multiplication and inter operation transfer provides a fast foolproof means for solving combined calculations.

In all calculations, the Tetractys operates in such a logical, orderly way that operations are easily understood; on the printed tape, operations and results are clearly identified by appropriate symbols. Tetractys features exclusive in the printing calculator field include: automatic short cut negative multiplication, automatic retention of a constant multiplier and of a constant dividend, automatic re-entry of the total of accumulated products for any subsequent calculation including multiplication and division without manual setting, automatic accumulation of quotients without manual setting, elevation of a number to any power within the machine's capacity and automatic squaring with no resetting required.

The Tetractys will be featured in an unusual display at the Olivetti exhibit, and complete information on the Tetractys and other Olivetti machines will be available to visitors.

THE WORK FACTOR COMPANY

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The WORK FACTOR Company exhibit is designed to acquaint visitors with the WORK FACTOR System of pre-determined times and with the other services of the Company.

Interesting applications, standard data, day work and incentive plans will be shown.

A section will be devoted to current WORK FACTOR research, especially in the area of mental processes and visual inspection.

Advanced sections of the forthcoming WORK FACTOR text book can be seen.

Displays will be made of WORK FACTOR applications in Japan and Europe.

Information will be available about other services including interesting work now being done in the fields of maintenance cost reduction and hotel management.

Members of the WORK FACTOR Staff will be available to explain the material on exhibit and to answer specific technical questions.

WEBER MARKING SYSTEMS

Division of Weber Addressing Machine Co., Inc., Mount Prospect, Illinois

The complete line of machines, hand devices and stencil systems for addressing and marking of labels, tags and cartons will be on exhibit. There will be a demonstration of the new Dual 80 Label Printing Machine which prints product and content identification labels at the rate of 105 per minute. There will also be demonstrations of the various stencil systems for addressing direct to shipping cartons. The company will also exhibit two types of shipping stencils which can be prepared as a by-product of the order invoice writing procedure.

NEW YORK TELEPHONE COMPANY

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A communications service that is custom engineered to meet the exacting requirements of each user is often the key to a successful automation program. Bell System can engineer and provide such communications service.

In the manufacturing field, for example, services are designed for Integrated Data Processing program which pull together widespread sales offices and plant operations and put orders, sales and inventory reports where you want them, when you want them.

Automatic sending and receiving equipment and typing reperforators, shown in the New York Telephone Company Workshop, are basic equipment at the data originating and data processing centers.

The Bell System can also provide telephone and video grade channels for the alternate use of the written word, the spoken word and direct card punch equipment.

INTERNATIONAL BUSINESS MACHINES CORPORATION

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IBM'S APR equipment, providing a new, fully integrated system designed specifically for the automatic collection of production data at the source of manufacturing operations, fills a long-standing need in industry.

Fast and flexible, APR can express itself both in machine and human language. It has the ability to collect, correlate, store and record accurate, up-to-the-minute production data in punched tape and cards, while printing out reports for supervisors on automatic typewriters located along the production line. The card and tape media, containing such variables as weight, count, length and temperature, together with related information identifying the product and process, are used as input to accounting machines.

APR's flexibility stems from the sixteen, newly developed basic components, or "building blocks," which are assembled in appropriate combinations to meet the requirements of widely varying production recording applications. They include automatic and manual input units, pre-punched card readers, printing card punches, control console, and remote typewriters. Each APR system consists of the components required on the basis of the number of production points to be covered and the nature of the manufacturing operation.

THE CONFERENCE BOOK SERVICE

3290 Columbia Pike, Arlington 4, Virginia

Members who attended the Seventh Annual Conference and Convention in Washington last year will remember the book exhibit which attracted so much attention there. Organized and arranged by the Conference Book Service, the primary purpose of the exhibit is to enable conference participants to see and to examine freely as comprehensive a collection of new and current works in fields of interest to Industrial Engineers as is likely to be found under one roof anywhere. Most American publishers are represented. A printed bibliography of all books exhibited will be available at the exhibit free of charge.

The exhibit provides an opportunity which is all too rare—the chance to inspect at first hand and without bother or obligation many of the important new books which are appearing so regularly these days. You are invited and encouraged to browse at will. Those wishing to purchase or order books may do so at the exhibit.

WORK, WORKERS, and WORK MEASUREMENT

By Adam Abruzzi

The principles for determining objective means of estimating and predicting workers' production rates, first presented in Dr. Abruzzi's WORK MEASUREMENT, are now widely accepted. This new book features a theory of work of which the measurement ideas of the previous book are but one part. Dr. Abruzzi first analyzes classical theories in terms of the "theory of games." He then examines the behavioral problems of workers at the work place and discusses their effect on measurement procedures. A new theory of both *work fatigue* and *work skill* emerges, and Dr. Abruzzi shows how these two aspects of his theory are related. He concludes by relating his new work theory to the concept of automation and shows that it is, in fact, verified by what happens in the automatic factory. *352 pages*, **$7.50**

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Written by 75 specialists, from a factual and how-to-do-it approach, and in concise, readable form, the book forms an invaluable reference and methods book for the engineer and for managers and administrators concerned with industrial engineering problems.

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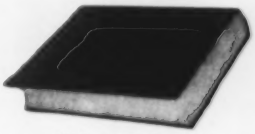

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